THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. VI.

No. VII.—JULY, 1909.

ORIGINAL ARTICLES.

I.—The Geology of the Lower Coal-measures of the Derbyshire and Nottinghamshire portion of the Yorkshire Coalfield.

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Introduction.

THE lithological character and sequence of the lower part of the Coal-measures of the Yorkshire Coalfield have been well known since the publication of the memoir by the Geological Survey in 1878. No connected account of the explorations in the equivalent measures of the Derbyshire and Nottinghamshire portion of the coalfield has been written; thus the close correspondence which exists between the lower part of the Coal-measures of Yorkshire and that of Derbyshire and Nottinghamshire is still generally unknown.

The sequence under consideration includes more than 800 feet of measures lying between the top of the First Grit of the Millstone Grit Series and a well-known Derbyshire seam, the Kilburn Coal. These lower measures continue from Yorkshire through Derbyshire with a north and south strike which changes to east and west on the southern border of the coalfield. Continuous escarpments of Millstone Grit form the western border of the coalfield, but on the south, with the exception of a small area of the First Grit, the measures below the Kilburn Coal are faulted down and buried under the Triassic rocks to the west of Nottingham.

The object of this paper is to discuss the evidence afforded by bore-holes and sinkings for the presence of these Lower Coal-measures on the southern margin of the Derbyshire Coalfield and their continuation under the Trias of Nottinghamshire; and further to show, by means of plotted sections, the marked southerly attenuation which occurs in the lowest portion of the sequence.

The recent trial shaft at the Kilbourne Colliery affords valuable evidence for the occurrence of these rocks in Derbyshire; from the details given in the Survey Memoir (1), Fig. 1, Section I, and Fig. 2, Section II, have been plotted to serve as a type with which to compare the sections described below.

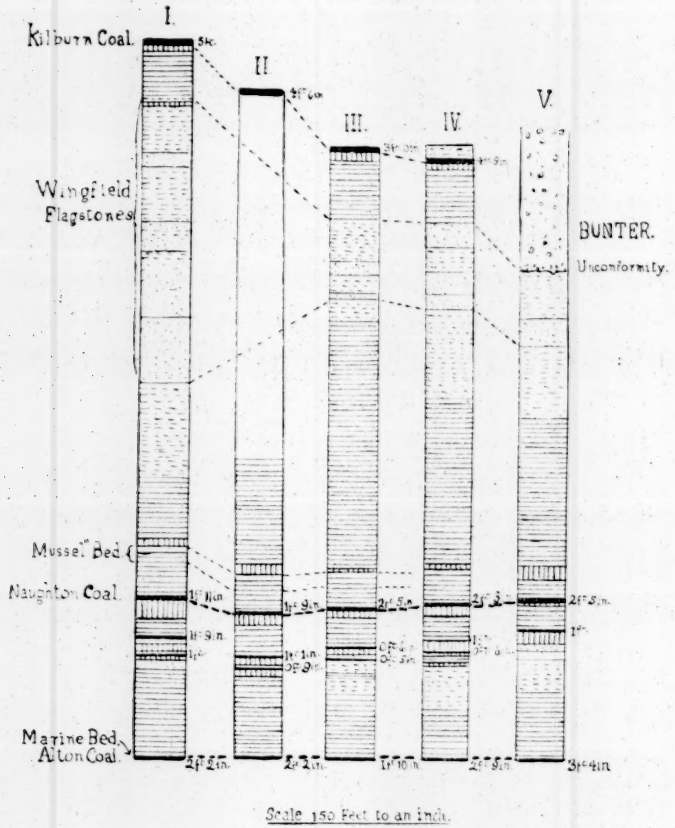

FIG. 1, Section I. New Shaft at Kilbourne Colliery.
,, II. New Sinking at Oakwell Colliery.
,, III. Boring at Little Hallam.
,, IV. Trial Shaft at Stanton Gate.
,, V. Boring at Ruddington.

Excluding thin coals, these measures contain in descending order four named seams—the Kilburn, Naughton, Alton, and Belperlawn Coals. Additional confirmatory evidence for the identification and correlation of sections is furnished by—

1. The presence of the Wingfield Flagstones some distance below the Kilburn Coal.
2. The occurrence of a marine bed in the roof of the Alton Coal.

The former is a group of sandstones, flagstones, and shales, which, because of its remarkable persistence and the bold escarpment to which it gives rise, was regarded by Green (2) as the most important rock of the Lower Coal-measures of the Yorkshire Coalfield.

The latter consists of a few feet of pyritous shale, with calcareous and pyritous nodules, containing numerous marine fossils of which the most common are *Pterinopecten papyraceus*, *Goniatites*, *Lingula*, and the remains of fish.

This marine bed provides a reliable and easily recognized datum-line for these lower measures, the base of which is clearly defined by the upper limit of the massive and persistent First Grit (Rough Rock).

Detailed Consideration of Sinkings and Borings.

So long ago as 1856 Smyth (3) gave for the Stanton district the following estimate for the thickness of the measures between the Kilburn Coal and the 'Bottom' Coal which "rests almost immediately upon the Millstone Grits":—

	ft.	in.
Kilburn Coal	5	0
Clunch	3	0
Honeycroft Rake	45	0
Measures	252	0
Civilly Rake	60	0
Coal, 'Furnace' (Naughton Coal)	2	3
Dale Moor Rake	21	0
Measures	96	0
Coal, 'Bottom' (Alton Coal)	2	0
Total	486	3

Subsequent explorations, whilst confirming the above estimate, have proved a further 50 feet of Coal-measures between the Alton Coal and a coal—the Belperlawn seam—which occurs on the top of the First Grit.

Trial Shaft at Stanton Gate Iron Works. (Fig. 1, Section IV.)—This shaft was sunk on the outcrop of the Kilburn Coal in 1877, at a time when much valuable local knowledge of the Lower Coal-measures had been obtained during the working of the numerous ironstone pits of the district.

This section is of importance, because the coal-seams, Ganister beds, and ironstone 'rakes' are correctly named and carefully described. The thickness of measures between the Kilburn and Alton Coals amounts to 480 feet, thus confirming Smyth's estimate of 1856.

Wollaton Colliery.—An old boring from the bottom of this shaft proved the measures from the Deep Hard Coal down to the Naughton Coal. The Black Shale (Silkstone) seam was proved, but no trace of the Kilburn Coal was found on the horizon where it was expected to occur.

The Little Hallam Boring near Ilkeston. (Fig. 1, Section III. and Fig. 2, Section IV.)—This deep boring for water was put down in 1896 by the Corporation of Ilkeston on a site between the outcrops of the Black Shale and the Kilburn Coals about three-quarters of a mile south of the town.

The first 500 feet were cut by percussive drill, and "as this part of the section was well known it was not accurately observed" (4); for this reason the measures above the Kilburn Coal[1] will not be considered

[1] The thickness of this coal as given in the boring section is probably incorrect.

here. The rest of the boring was done by diamond drill. Owing to the indefinite, not to say mistaken, lithological descriptions the section is somewhat misleading. Fortunately a small collection of cores has been preserved, from an examination of which I have been able to correct and supplement the section. The Kilburn Coal, the Wingfield Flagstones, the Naughton, Alton, and Belperlawn Coals can be identified.

At 1110 feet deep, 25 feet above the Naughton Coal, there occurs a well-marked shell-bed containing many dwarfed specimens of *Carbonicola acuta*.

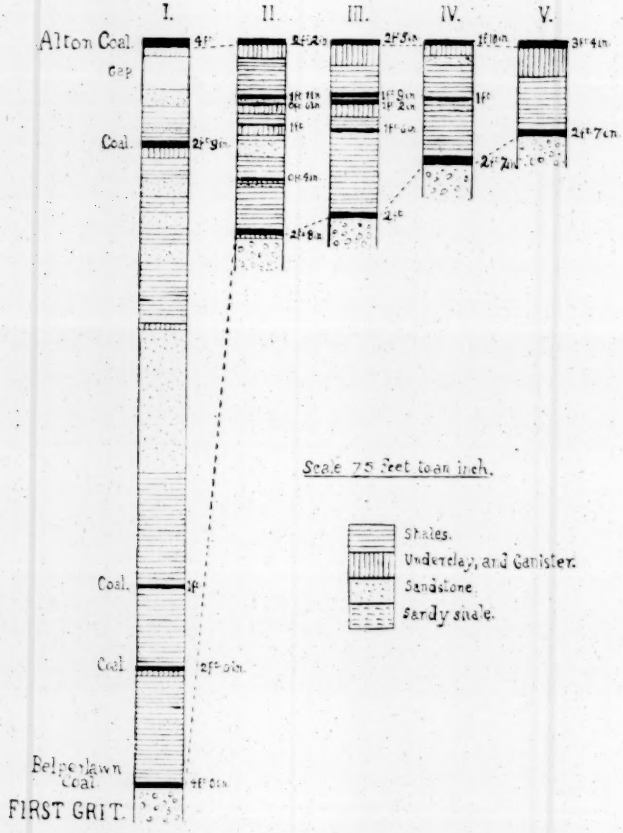

Fig. 2. Section I. General Section at Ambergate.
,, II. New Shaft at Kilbourne Colliery.
,, III. Water Works Shaft at Smalley.
,, IV. Boring at Little Hallam.
,, V. Boring at Ruddington.

At three horizons the term 'burr' is used. The rock so described is composed of numerous small spherulites of siderite set in a very

fine-grained light-grey matrix of marl. A fourth bed of siderite, 18 inches thick, forms part of the fireclay floor of the Alton Coal, immediately overlying a bed of hard grey Ganister. I have found similar siderites at various horizons in the Nottinghamshire Coalfield: they closely resemble the Staffordshire example recently described by Dr. Teall (5).

The Ruddington Boring. (Fig. 1, Section V, and Fig. 2, Section V.)—Several references to this important boring have been made (6), and the section has recently been published by the Geological Survey (7). After penetrating 670 feet of Trias the boring proved 440 feet of Lower Coal-measures and 760 feet of Millstone Grit. The following fossils were obtained from an unknown depth by the late James Shipman, F.G.S. (8):—

Carbonicola acuta.
C. acuta, var. *rhomboidalis.*
C. aquilina.
Anthracomya modiolaris.
Acanthodes Wardi.

Owing to their wide range these fossils yield no assistance in identifying the horizon reached in this boring.

From a study of a nearly complete series of cores I am able to add the following important details concerning this boring. The published account places the surface of the Coal-measures at a depth of 687 feet; but it must occur a few feet higher, because I obtained pith-casts of *Calamites* sp. at 682 feet. The upper 20 feet of Coal-measures consist of red and grey micaceous sandstone with thin beds of blue marl. As these red measures pass downwards into typical grey sandstones and sandy shales of the Wingfield Flagstones, they must be regarded as Wingfield Flagstones stained by percolation from the overlying Bunter. These beds contain numerous badly preserved plant-remains, including—

Calamites sp., cf. *varians*, Sternb.
Cordaites sp.
Crossotheca sp.

At 689 feet and at 698 feet are two thin bands of breccia composed of angular fragments of marl and hæmatite set in a red sandy matrix. This suggests that erosion has taken place.

The Coal-measures were entered below the Kilburn Coal. Conclusive evidence of the horizon reached in this boring is furnished by the coal 3 ft. 4 in. thick at a depth of 1072 ft. 9 in. The dark pyritous roof-shale in contact with the coal is crowded with flattened marine fossils, including—

Pterinopecten papyraceus.
Gonatites sp.
Schizodus sp.

The floor of the seam is a hard, grey, compact Ganister passing downwards into fireclay. This coal must, therefore, be the Alton Coal.

It has been generally assumed that from Nottingham to Ruddington the Coal-measures dip steeply to the north, but an examination of the cores (which have a diameter of 7 inches) does not confirm this opinion; with the exception of a few feet of false-bedded sandstones belonging to the Wingfield Flagstones, the Coal-measures appear to lie in a horizontal position. After allowing for the faults proved in the

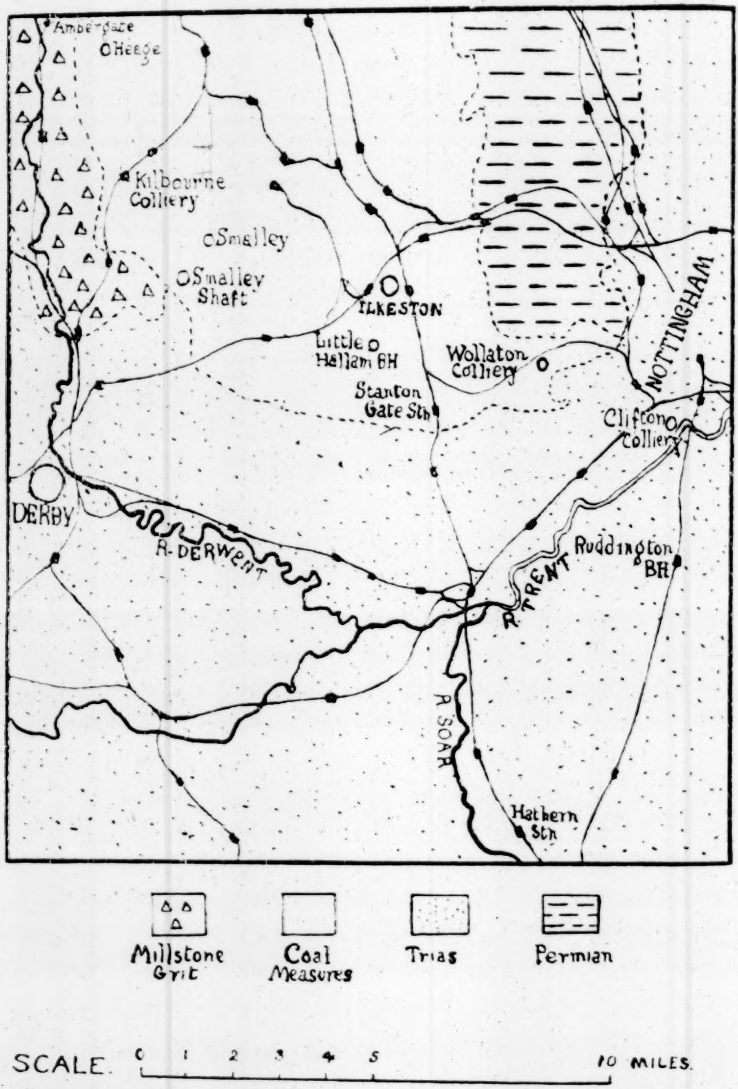

FIG. 3. Sketch-map showing the position of borings and shafts in the Derbyshire and Nottinghamshire Coalfield.

workings of the Deep Hard and the Deep Soft Coals at the Clifton Colliery, 3 miles north of Ruddington, and also for the known southerly rise of the Coal-measures under Nottingham, the position at Ruddington can only be accounted for by assuming the presence of

an additional east and west fault, or faults, having a considerable upthrow to the south, in the 1½ miles of unproved ground north of the Ruddington borehole.

Oakwell Colliery, Ilkeston. (Fig. 1, Section II.)—The workings in the Kilburn Coal at this colliery having recently encountered a fault with an upthrow of 95 yards, the opportunity was taken to try the Ganister Coals by means of a trial shaft sunk from a level driven through the fault. The Naughton and Alton Coals were proved. The section closely agrees with the Kilbourne section, and confirms my reading of the adjacent Little Hallam Boring.

Underlying a bed of white clunch, 37 feet above the Naughton Coal, was a shell-bed with numerous specimens of *Carbonicola acuta* and *C. aquilina*.

The Alton Coal, with its marine bed roof, showed the following section :—

	ft.	in.
Black Shales (marine bed)	1	4
Coal	1	11 to 2 ft. 4 in.
Ganister floor) White fireclay)	6	0

The black roof-shales are crowded with flattened fossils, and contain large calcareous and pyritous nodules in which perfect unerushed fossils occur. The following were collected :—

Lingula mytiloides.
Pterinopecten papyraceus.
Posidoniella laevis.
P. minor.
Gastrioceras carbonarium.
G. Listeri.
G. coronatum.
Dimorphoceras Gilbertsoni.
Pleuronautilus sp.
Orthoceras (more than one species).
Elonichthys sp.
Megalichthys Hibberti.
Acanthodes sp.

General Considerations.

1. *Comparison with the Yorkshire Coalfield.*

The Kilburn Coal.—This important seam is an excellent house-coal throughout the southern portion of the Derbyshire Coalfield, with an average thickness of 5 feet on the western and southern outcrops, but diminishing locally in the workings on the easterly dip. It has not yet been proved under the Trias of Nottingham. Traced northward the seam thins away to less than 2 feet in the Chesterfield area, and further north it is represented only by its underclay. In the southern portion of the Yorkshire Coalfield an underclay occurs on the same horizon, some way above the Elland Flagstones, while north of Huddersfield the Better Bed Coal comes on over this underclay; and this coal, like its equivalent the Kilburn Coal, is immediately overlain by a 'bone-bed' composed of fragments of fish-remains (9).

The Wingfield Flagstones.—The bold feature formed by the outcrop of this rock is known to extend throughout the whole length of the Derbyshire into the Yorkshire Coalfield, where it is called the Elland Flagstone. The work of Hull and Green, and the more recent work of Gibson and Wedd, has resulted in the correlation of the Elland Flagstones with the Upholland Flags of the Lancashire Coalfield, and with the Woodhead Sandstones of the Cheadle Coalfield of

North Staffordshire. In this area it is difficult to define the upper and lower limits of the group, owing to the replacement of part of the sandstones by sandy shales, but even so far south as Ruddington, where the 'flags' are wholly wanting, the sandstones are still quite coarsely grained.

The Alton Coal.—With the possible exception of the area south-west of Chesterfield (10), this coal, with its accompanying marine bed roof, is persistent throughout the Derbyshire Coalfield into Yorkshire, where it becomes the well-known Ganister or Halifax Hard Coal, which invariably has a marine bed roof.

The correlation of this coal with the Bullion Coal of Lancashire and with the Crabtree Coal of North Staffordshire is now well established, and is regarded as strong evidence for the formation of the Coal-measures of the Midland Counties in one basin of deposition.

In Yorkshire the Ganister Coal has been extensively worked as an engine coal. It is interesting to notice that its equivalent in this area, the Alton Coal, possesses identical properties, being a pyritous, quick-burning, good coking coal of variable thickness, used in the past mainly for engine purposes.

The Belperlawn Coal.—This coal, with its underclay, rests immediately upon the top of the First Grit. Towards the south it thins away (see Fig. 2), and, by the intercalation of shale bands, deteriorates in quality until at Ruddington it contains only 10 inches of coal.[1] This seam is the equivalent of the "thin coal and underclay" which is constantly found on the top of the First Grit of the Yorkshire and Lancashire Coalfields.

2. *The Southerly Attenuation of the Coal-measures.*

Figs. 1 and 2 illustrate the general southerly decrease in thickness of these lower measures of the Yorkshire Coalfield. Fig. 2 shows that this attenuation is most marked in the measures below the Alton Coal. It is accompanied by a gradual and progressive loss of the associated sandstones and thin coals, until at Ruddington the measures between the Alton and Belperlawn Coals consist of only 32 feet of fireclay and shales. A similar attenuation occurs in the equivalent measures of the Cheadle Coalfield of North Staffordshire. These facts afford strong confirmatory evidence that in this area and for these lowest measures the old rocks flanking the Charnwood Range were part of the southern margin of deposition of that continuous sheet of Coal-measures of which the Lancashire, Yorkshire, and North Staffordshire Coalfields are the remains.

List of Fossils from the Lower Coal-measures of Nottinghamshire and Derbyshire.

Calamites sp., cf. *schutzei*, Stur.
C. sp., cf. *varians*, Sternb.
Cordaites sp.
Sphenophyllum cuneifolium, Sternb.
Stigmaria ficoides, Sternb.
Sigillaria sp.
Crossotheca sp.
Lepidodendron aculeatum, Sternb.
L. lycopodioides, Sternb.
Lepidophloios sp.
Lepidostrobus sp.
Carbonicola robusta, J. de C. Sow.

[1] Nevertheless, the sinking at the Oakwell Colliery, Ilkeston, is being continued to the Belperlawn Coal.

Carbonicola nucularis, Hind
C. turgida, Brown
C. aquilina, Sow.
C. acuta, Sow.
C. acuta, var. *rhomboidalis*, Hind
Naiadites modiolaris, J. de C. Sow.
Anthracomya modiolaris, Sow.
A. cf. *lævis*, Dawson, var. *scotica*, R. Eth., jun.
Spirorbis sp.
Lingula mytiloides, Sow.
Spirifer sp.
Pterinopecten papyraceus, J. Sow.
Posidoniella minor, Brown
P. lævis, Brown
Gastrioceras Listeri, Mart.
G. carbonarium, Von Buch
G. coronatum.
Glyphioceras bilingue (?), Salter
Dimorphoceras Gilbertsoni, Phill.
Pleuronautilus sp.
Orthoceras (more than one species).
Gasteropoda (of several species).
Acanthodes Wardi, Egert.
Sphenacanthus hybaides, Egert.
Calacanthus elegans, Newb.
Megalichthys Hibberti, Agass.
M. intermedius, A. S. Woodw.
Rhizodopsis sauroides, Will.
Elonichthys Aitkeni, Traq.
E. Binneyi, Traq.
Platysomus tenuistriatus, Traq.
Rhadinichthys monensis, Egert.
Mesolepis scalaris, Young
M. micropterus, Traq.
Haplonchus sp.

Distribution of the Fossils.

The scarcity of exposures in this area, and the difficulty of attaching names to some of the specimens owing to the unsatisfactory state of our present knowledge of the Cephalopoda and Gasteropoda of the Coal-measures, combine to render the list of fossils only a partial indication of the life of the period. Within such a relatively small thickness of measures there is no restriction of particular species to definite horizons.

Plants.—The few plants are all common species; they occur chiefly in association with the coal-seams, and in the sandy beds of the Wingfield Flagstones.

Fish.—Fragmentary scattered fish-remains occur in almost all the shales; they become numerous in the roof-shales of the Kilburn, Naughton, and Alton Coals, forming thin bone-beds composed of scales, teeth, bones, and spines.

The bands of concretionary nodules of clay ironstone, locally called 'Rakes', have in the past yielded numerous perfect specimens of fish.

Remains of fish are usually found not to extend over wide areas. Of these fish-beds, only that in the marine bed over the Alton Coal is persistent throughout and beyond this district; its range would appear to be coextensive with that of the marine bed. Although no attempt has been made to show its persistence in other areas, it has been several times observed in the equivalent marine bed of the Lancashire, North Staffordshire, and Yorkshire Coalfields.

Freshwater (or Estuarine) Mollusca. — The zone fossil for this sequence and the succeeding measures up to the Deep Hard Coal is *Carbonicola robusta*. The range of *C. nucularis* is a little wider, but outside the zone of *C. robusta* it is very rare. The specimens of *C. acuta* are sometimes dwarfed, and similar dwarfed *C. acuta* have been recorded from the Ganister series of other coalfields (11).

It is interesting to observe (see Fig. 1) that at least one of these 'Mussel Beds' is persistent for some distance, forming a definite horizon of local value in the identification of shaft sections.

Marine Fauna.—With the exception of a bed containing only *Lingula*

which occurs below the Alton Coal in the Kilbourne shaft, the marine fossils are found to be restricted to the roof of the Alton Coal.

Conclusion.

The Alton Coal and its marine bed have thus been proved to persist from the outcrop in Derbyshire as far as Ruddington, 15 miles to the south-east, without showing any signs of thinning away.

On the east side of the Charnwood Range borings have shown the Coal-measures to be absent (e.g. at Hathern, 7 miles south-west of Ruddington) (12). It would therefore appear that these Lower Coal-measures continue to the south of Ruddington and finally end abruptly against the older rocks flanking the Charnwood Range.

It is impossible as yet to correlate the Yorkshire and Leicestershire Coalfields since very little is known of the lower measures of the Leicestershire Coalfield, which contains no workable coal-seams. In future explorations it is suggested that search should be made for this Alton Coal marine bed, which would provide a much needed datum-line of prime importance in the correlation of the Leicestershire Coalfield with the other coalfields of the Midland province.

Owing to the strongly unconformable cover of Trias which conceals the Coal-measures to the south of Nottingham there is always the possibility that future borings may (as at Ruddington) unexpectedly encounter these Lower Coal-measures. In such a case it will no longer be necessary, as in the past, for borings to be continued below the Alton Coal marine bed, the explorations described above having definitely proved that in this area the Ganister Coals are of no present value.

I wish to express my indebtedness to the work of Dr. Gibson and Mr. Wedd, B.A., as contained in the recent Survey Memoir on South Derbyshire. My best thanks are due to Mr. E. A. Newell Arber, M.A., Dr. Hind, and Dr. Traquair for assistance in identifying the fossils; to Professor J. W. Carr, M.A., and Dr. Swinnerton, of University College, Nottingham, for facilities in carrying out the work and for permission to break up and examine a series of cores from the Ruddington Boring; to G. E. Coke, Esq., F.G.S., for further cores from Ruddington; to H. J. Kilford, Esq., the Ilkeston Borough Surveyor, for permission to examine cores from the Little Hallam Boring; and to P. M. Chester, Esq., General Manager of the Oakwell Collieries, Ilkeston, for kindly allowing me to inspect the new sinking at that colliery.

References.

1. Gibson, W. "Geology of the Southern Part of the Derbyshire and Nottinghamshire Coalfield": Mem. Geol. Surv., 1908, pp. 183–6.
2. Green and others. "Geology of the Yorkshire Coalfield": Mem. Geol. Surv., 1878, pp. 123–4.
3. Smyth, W. W. "Iron Ores of Great Britain": Mem. Geol. Surv., 1856, pt. i, p. 39.
4. Ashworth, J. Coll. Guard, vol. lxxii, pp. 823 and 1111.
5. Teall, J. J. H. "Geol. of the North Staffs. Coalfields": Mem. Geol. Surv., 1905, p. 70.
6. Kendall, P. F. "Roy. Comm. on Coal Supplies," 1905, pt. ix, App. III.
7. Gibson, W., and others. "Geology of the Country between Newark and Nottingham": Mem. Geol. Surv., 1908, App. I, pp. 112–13.

8. Shipman, J. Manuscript notes, in University College, Nottingham.
9. Davis, J. W. Quart. Journ. Geol. Soc., vol. xxxii, p. 332.
10. Gibson, W., and others. "Summary of Progress for 1906": Mem. Geol. Surv., p. 11.
11. Hind, W. "Monograph on *Carbonicola*, *Anthracomya*, and *Naiadites*," 1895, pt. ii, Section 7: Pal. Soc., vol. xlix.
12. Strangways, C. Fox. "Geology of the Leicestershire and South Derbyshire Coalfield," 1907: Mem. Geol. Surv.

II.—Geology and Petrology of the Intrusions of the Kilsyth–Croy District, Dumbartonshire.

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(PLATE XII.)

I. Introduction.

THE group of intrusions of which this paper treats is a part of a series of intrusive rocks piercing the Carboniferous strata of the Midland Valley of Scotland. As a rule, they have forced their way into the Carboniferous Limestone Series in layers roughly parallel to the stratification. At the surface they stand out as rough, craggy hills, often of considerable elevation, rising abruptly out of the plain of the Carboniferous sediments, and frequently ending off in a vertical escarpment of bare rock. They generally confront, at a distance of 1 or 2 miles, the terraced escarpments of Lower Carboniferous lavas, which bound the Midland Valley on the north, west, and south-west.

These intrusions are intimately connected with the great series of E.–W. dykes which traverse the Midland Valley, and form, with them, a group of considerable petrographical individuality, which is represented in all parts of the world.

On the ground the Kilsyth–Croy group consists of four separate masses, extending roughly in a S.W.–N.E. direction. It is connected with three of the great E.–W. dykes.[1]

The two main outcrops, upon which stand the villages of Kilsyth and Croy respectively, extend from Twechar to Banton, a distance of 5 miles, and are separated by the ancient alluvial trough now occupied by the River Kelvin and the Forth and Clyde Canal. This trough, however, cuts through the north-eastern prolongation of the Croy mass. The third outcrop is a thin, sinuous intrusion, about 1 mile south of the Croy mass, which is injected into a higher horizon. Another small mass occurs abutting against the main boundary fault to the north of Kilsyth.

A short general account of the nature and occurrence of these rocks is given in the Geological Survey Memoir (1879) on Sheet 31.[2] In his classic paper on the Carboniferous Dolerites,[3] Allport described the rocks of Gernal Brae and Auchinstarry in the Kilsyth district. Sir A. Geikie has treated of the general relations of these intrusions and the great E.–W. dykes, first in his paper on the Carboniferous Volcanic

[1] See Sheet 31 of Geological Survey of Scotland.
[2] pp. 43–6.
[3] S. Allport, Q.J.G.S., 1874, vol. xxx, p. 553.

Rocks of the Firth of Forth,[1] later in his Presidential Address to the Geological Society in 1892,[2] and finally a detailed account has been given by him in his *Ancient Volcanoes of Great Britain*.[3] Dr. Teall[4] has described rocks from Kilsyth and Croy. Mr. Monckton has described similar rocks from the Stirling district,[5] and Dr. Falconer from the Bathgate Hills.[6]

II. Structure of the Kilsyth and Croy District.

The rocks of this area belong mainly to the Carboniferous Limestone Series. They are bounded by the Millstone Grit on the west, south, and east, and by the Calciferous Sandstone and its intercalated lavas to the north. The boundary here is the main E.–W. fault. The general succession is given below. Only the outstanding horizons of limestone, coal, etc., are given. It must be understood that these are separated from one another sometimes by hundreds of feet of sandstone and shale.

Millstone Grit = Roslin Sandstone.

Carboniferous Limestone Series.
- Castlecary Limestone.
- Calmy or Arden Limestone.
- Bishopbriggs Sandstone.
- Index or Cowglen Limestone.
- Blackband Ironstones, Nos. 1–4, with Main Coal of Meiklehill near top.
- Main Coking Coal of Kilsyth.
- Hosie's Limestones.
- Hurlet Limestone.

Calciferous Sandstone Series, with intercalated volcanics.

The dominant structural feature is the sharp anticline in the Carboniferous Limestone Series, locally known as "The Riggin", which runs in a south-west to north-east direction, from Twechar to Banton. The general strike of the beds is therefore south-west to north-east, but the country is much broken by a series of E.–W. faults, the largest of which brings the Calciferous Sandstone and its volcanics into contact with the Carboniferous Limestone Series to the north of Kilsyth. There is also a set of smaller faults, the general direction of which is from north-west to south-east. In the course of the revision of the district by the Geological Survey it has been shown that the structure of the Riggin is not so simple as formerly supposed, but that there is a series of more or less parallel wave-like troughs and ridges having a general N.E.–S.W. trend.[7]

III. Geology of the Intrusions.

Horizon.—The intrusions are, as a whole, roughly conformable to the bedding, although in places they gradually transgress. The main

[1] T.R.S.E., 1879, vol. xxix, p. 505.
[2] Q.J.G.S., 1892, vol. xlvii, proc. 105.
[3] Vol. i, pp. 417–23, 446–61; ii, pp. 140–3, 155–8.
[4] *Brit. Petrog.*, 1888, p. 192.
[5] Proc. Geol. Assoc., 1891–2, vol. xii, p. 242, with petrog. appendix by J. G. Goodchild; also Q.J.G.S., 1895, vol. li, pp. 480–91.
[6] T.R.S.E., 1905–6, vol. xlv, pt. i, p. 137.
[7] *Summ. Prog. Geol. Surv.*, 1905, p. 124.

mass of the Kilsyth–Croy intrusion, for instance, lies between the Index Limestone and the Kilsyth Coking Coal; yet in the south-western prolongation of the Croy mass it has transgressed so as to actually overlie the former seam. To the north-east, however, it transgresses downwards.[1] A detailed section across the area from the north-west to south-east shows at once that the apparently separate masses of Kilsyth and Croy are detached portions of the same intrusion thrown off on either side of the denuded anticline of the Riggin (see Fig. 1). In the extreme north-east of the area, towards Denny, the two outcrops unite where both the intrusion and the anticline are beginning to die out. The sinuous outcrop 1 mile to the south of the Croy Mass belongs to a thin intrusion injected on a platform some hundreds of feet higher in the series. To the north of the Kilsyth Mass a small intrusion occurs on a lower platform, and abuts against the boundary fault between the Carboniferous Limestone Series and the Calciferous Sandstone. It is probably the same as that which occurs in a deep bore at Wester Bedeow near Kilsyth. This horizon is about 270 feet above the Main Coking Coal.

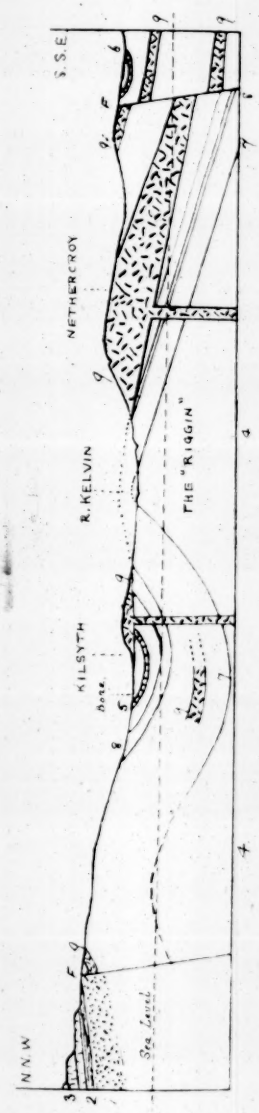

Fig. 1. Diagrammatic Section across the Kilsyth-Croy Area.

1, Calciferous Sandstone; 2, Cement-stones; 3, Calciferous Sandstone lavas; 4, Carboniferous Limestone Series; 5, Index Limestone; 6, Calmy Limestone; 7, Kilsyth Coking Coal; 8, Blackband Ironstones; 9, Diabase intrusions; F, Faults. Scale: horizontal, 1 inch = 1 mile; vertical, 1 inch = 1000 feet.

The horizon of the intrusions becomes lower as one proceeds in a north-westerly direction. The great sill of Stirling in this direction is injected just above the Hurlet Limestone, at the base of the Carboniferous Limestone Series.

The intrusion trending southward from Myot Hill, which appears to be the southern continuation of the Stirling mass, is just under the horizon of the Main Coking Coal at the outcrop. A boring in Messrs. A. & G. Moore's Castlerankine field, half a mile east of the outcrop, shows that in this distance the igneous rock has transgressed until it is at least 400 feet below the Coking Coal.

[1] Ibid., 1906, p. 104.

Form.—The form of the Kilsyth-Croy intrusion is that of a flattened and attenuated laccolite, as is well shown in sections kindly supplied by the Carron Co. and by William Baird & Co. (see Fig. 1). In the Nethercroy Pit, worked by the Carron Co., the sedimentaries and the igneous rock dip to the south at an angle of 20°. The 'whin' occupies most of the surface, rising to a height of 481 feet above sea-level. At its thickest part, under the Antonine Wall, it is represented as 346 feet thick in the section supplied by the Carron Co., and this is not the original thickness, as the surface has suffered considerable denudation. But at a point 780 yards south of the Antonine Wall the total thickness is only 190 feet. The greatest thickness in that extension of the laccolite upon which the town of Kilsyth stands is about 150 feet; and although this mass has suffered some denudation, it seems probable that in this direction there is a considerable diminution from the maximum thickness that occurs under the Antonine Wall. At Drumgrew, 2½ miles south-west of the latter point, the thickness has been proved in a bore to be 108 feet.

At the Neilston Pit, north of Kilsyth, and due north of the point of maximum thickness, the igneous rock has been proved to a depth of 100 feet.

Owing to its relatively small thickness as compared with its horizontal extent, the laccolite has caused a quite insignificant arching of the overlying strata.

The term 'laccolite' is used here in the sense of a lens-shaped body of igneous matter supplied through vertical dykes, both upper and lower surfaces being slightly transgressive, whereas in the typical laccolites of the Henry Mountains both surfaces are conformable to the strata.[1]

Relations of the E.–W. Dykes to the Laccolites.

Two long E.–W. dykes terminate in the Croy mass. The more southerly of these begins about 3 miles south of Linlithgow, and on Sheet 31 of the Geological Survey is mapped as cutting through the great sill at Torphichen. After passing through the village of Cumbernauld it is represented as cutting through the sinuous intrusion south of the Croy mass, and before terminating in the laccolite throws off another small protrusion to the south. Its total length is 17 miles. The northerly dyke, passing through the village of Dullatur, continues in a more or less parallel course to that of the Cumbernauld dyke, at a distance of 1 to 1½ miles. It is also represented as cutting through the Torphichen sill, and also through the Kilsyth-Croy laccolite. Its total length is 20 miles. The third dyke is only 2 miles long. It is represented on the Survey map as cutting through the extreme south-western prolongation of the Croy mass.

There can be little doubt but that these dykes stand in the relation of feeders to the intrusions. In the Nethercroy section before cited, a thick vertical dyke (100 feet) rises through the strata, and joins the base of the laccolite in such a way as to leave no doubt that it is the duct through which the igneous material was supplied. This dyke is almost certainly continuous with the Cumbernauld.

[1] Gilbert, *Geology of Henry Mountains*, 1877, p. 19.

A section kindly supplied by the Baird Co. of their workings at Croy and Kilsyth also shows a 100 feet dyke rising through undisturbed strata and joining the base of the laccolite under the town of Kilsyth. On the Geological Survey map the Dullatur dyke is represented as cutting the Croy mass in the neighbourhood of Dullatur. Inside the boundary its trend alters from due E.–W. to E.S.E.–W.N.W. I have been unable to trace in the field the evidence upon which this change of trend was based; possibly it was based upon underground evidence available at the time of the original survey. It is significant, however, that if this change of trend be accepted, and if the dyke be continued in the new direction, it would appear in the position of the 100 feet dyke encountered in the Baird workings. It is highly probable, therefore, that the latter and the Dullatur are one and the same dyke.

The evidence, then, seems to point to the conclusion that the material of the Kilsyth–Croy laccolite was supplied through the ducts represented at the surface by the Dullatur and Cumbernauld dykes, and underground by the thick dykes found in the Baird and Carron workings respectively. This conclusion is supported by the following facts:—

1. The dykes terminate in the laccolite, and appear beneath it in the position of ducts.

2. The thickest part of the laccolite occurs between the two dykes, but nearer to the Cumbernauld dyke, suggesting that the latter supplied most of the material.

3. The laccolite seems to thin away more rapidly to the north and south of the point of maximum thickness, i.e. in directions at right angles to the direction of the dykes, than in the opposite direction, as might be expected if the dykes are the feeders of the laccolite.

Moreover, if lines are drawn connecting points of the same thickness on the laccolite, these are seen to be ellipses of which the major axes are parallel to the E.–W. dykes, although the S.W.–N.E. direction of extension of the laccolite itself is conditioned by the anticline of the Riggin.

4. There is complete petrographical identity between the laccolite and the dykes.

Age of the Intrusions.

The Kilsyth–Croy laccolite appears to have partaken of the flexures of the strata into which it is intruded, and is broken by both E.–W. and N.W.–S.E. faults. There is no conclusive evidence in this district as to the relation of the dykes to the faulting. Four miles to the east of Dullatur the Dullatur dyke is mapped as uprising along a small E.–W. fault. Still further to the east, at Cardrum Moss, there is a slight break in the continuity of the dyke, which may possibly be due to faulting.

In the Denny district the thin sills encountered in Messrs. A. & G. Moore's Castlerankine workings seem to cut through minor faults without dislocation.

The relations of the similar masses of intrusive rocks in the Midland Valley of Scotland outside our immediate district to the main faulting

are very much the same. Sir A. Geikie[1] believes that the large intrusive masses of Linlithgowshire are processes from the long dykes. Thus the dyke running eastward from Cadder and Bishopbriggs in the neighbourhood of Glasgow has no fewer than four large appendages, which are in turn cut by younger E.–W. dykes. He also remarks the petrographic identity of the rocks of the dykes and laccolites. He connects these intrusions with the puy eruptions of the Carboniferous Limestone period. "The remarkable group of sills between Kilsyth and Stirling may quite possibly be connected with a group of vents lying not far to the eastward, but now buried under the higher parts of the Carboniferous Limestone, Millstone Grit, and Coal-measures."[2]

The revision of the Bathgate district by the Geological Survey has shown that in some cases the dykes cut the sills, but that in one case at least, at the Knock in the Bathgate Hills, a N.–S. intrusion, continuous with a faulted sill, cuts through one of the E.–W. dykes.[3]

The Survey are also inclined to believe that the dykes cut the sills in the Kilsyth district and that they are later than the faulting.[4]

To summarize, the relations of the laccolites and dykes to each other, and of both to the faulting, appear to be contradictory in different parts of the Midland Valley. The difficulty is probably due to an assumption of strict contemporaneity for the various intrusions, and also for the faulting; whereas it is more probable that both intrusions and faulting, whilst belonging to the same general epoch, were a series of events extending over a long period of time. The earlier intrusions would then be shifted by the later faulting, and the later intrusions would cut through the earlier faults without dislocation.[5]

If the intrusions are in general contemporaneous with the faulting, they belong to that great period of earth-buckling which took place at the end of the Carboniferous and the beginning of the Permian period. The great E.–W. dykes cut through all the strata of the Midland Valley up to the drift, and are therefore post-Carboniferous. None of the E.–W. dykes, however, are found cutting the Permian Red Sandstones of Ayrshire. In all probability these intrusions were a phase of the formation of the great sunken block of strata—the great Rift Valley—which forms the Midland Valley of Scotland. It is a striking fact that the peculiar hybrid petrographic type, granophyric diabase, which forms these intrusions, very frequently occurs in these long massive dykes and their accompanying protrusions in connection with block faulting.

A mass of evidence has now accumulated in support of the late Palæozoic age of these intrusions. Whilst Sir A. Geikie connects the great group of sills from Milngavie by Kilsyth to Stirling with the Carboniferous Limestone puys, he classes the Linlithgowshire group, connected with the more southerly E.–W. dykes, as Tertiary.[6] As before stated, the feeders of the Kilsyth–Croy laccolite appear to cut

[1] *Ancient Volcanoes of Great Britain*, 1897, vol. ii, p. 157.
[2] *Ancient Volcanoes*, vol. i, p. 447.
[3] *Summ. Prog. Geol. Surv.*, 1904, p. 118.
[4] Ibid., 1905, p. 124.
[5] See *Ancient Volcanoes*, vol. ii, p. 158.
[6] *Ancient Volcanoes*, vol. ii, p. 10.

the Linlithgowshire intrusions, and are therefore of later date. If the northern group is of late Palæozoic age, so then are the Linlithgowshire intrusions. Professor Judd is of the opinion that some of the great E.–W. dykes are of Carboniferous age, but some, like those of Eskdalemuir and Cleveland, are undoubtedly Tertiary.[1] The latter may be distinguished petrographically from the Palæozoic dykes. They contain no micropegmatite, have a more basaltic structure, a more acid chemical composition, and are frequently porphyritic. Dr. Teall has remarked the difference between the two sets of dykes in the north of England occurrences.[2] The Tertiary dykes (Cleveland and Acklington) have a SiO_2 percentage of 57–9 and a sp. gr. 2·7–2·8. The earlier dykes (Hett and High Green) have a SiO_2 percentage of 50–3 and a sp. gr. of 2·96. The latter, therefore, correspond exactly with such of the dykes and connected sills of Central Scotland as have been analysed.[3] Recent survey work in Scotland has added much further evidence in favour of the pre-Tertiary age of the great E.–W. dykes of Central Scotland.[4]

IV. Petrology.

The rocks to which the following description applies are those of the Kilsyth–Croy, Stirling, and Milngavie laccolites, and the great E.–W. dykes of Bishopbriggs, Dullatur, Cumbernauld, Blanefield, Whistlefield, and Rowardennan. They are all diabases containing plagioclase, augite, and iron-ores, with a ground-mass of micropegmatite.

Megascopic Characters.

The main mass of these intrusions is composed of a grey, medium-grained, phanero-crystalline rock, hereinafter referred to as the 'normal' type. The grey colour is due to the blending of white and black minerals, the former felspars and micropegmatite and the latter augite and iron-ores. The micropegmatite is not recognizable as such in the normal rock, but in a coarser variety, which occurs sporadically towards the centre of the mass, it appears as large pink areas, and the augite tends to take on a long blady form. This rock consequently closely resembles some syenites and diorites, and frequently figures as such in dealers' catalogues. The marginal facies is a dense, black, basaltic rock, breaking with a conchoidal fracture, and sometimes porphyritic with felspar. Throughout the rock, but much more frequently towards the centre of the masses, there are to be found ramifying, anastomosing veins and strings, up to 2 inches in diameter, of a light-coloured acid material, the so-called segregation veins.

As a larger structural feature, the rock frequently occurs in a rude columnar form, to be seen in the larger quarries and in the natural escarpments. It weathers into large cuboidal blocks with rounded edges and corners. In an extreme phase of weathering it breaks down to a brown or red earth containing exfoliating spheroids of less decomposed rock.

[1] Q.J.G.S., 1889, p. 209.

[2] Q.J.G.S., 1884, vol. xl, pp. 209–47, and *Brit. Petrog.*, 1888, p. 266.

[3] See petrographical part of paper.

[4] See Memoir on Cowal district, 1897, p. 147, and *Summ. Prog. Geol. Surv.*, 1904–6, *op. cit.*

The sp. gr. of the normal variety varies from 2·90 to 2·93, whilst a coarse rock with large areas of pink micropegmatite from the Dumback Quarry at Croy has a sp. gr. of 2·82.

Microscopical Characters.

In thin section the normal rock is found to consist of a framework of interlocking crystals of plagioclase, augite, and iron-ores, with micropegmatite occupying the interspaces and generally playing the part of ground-mass. Hypersthene occurs sporadically with the augite. Among the secondary minerals are hornblende, chlorite, biotite, serpentine, calcite, and a green pleochroic bastite.

The felspars give long columnar sections, with the edges in the prism zone well defined, but terminations rarely recognizable. Squarish untwinned sections, parallel to 010, are rather abundant; Carlsbad and albite twinning is common, but the pericline is distinctly rare. The maximum extinction angle in albite-twinned sections giving symmetrical extinction is about 28°, which corresponds to a composition Ab_2 An_3, and indicates a labradorite of medium basicity.

Chemical zoning is very prominent. Whilst the interior of a crystal may give the maximum extinction angle, the border may give straight extinction, thus indicating a variation in composition from labradorite to oligoclase. This zoning is most pronounced in the square untwinned sections parallel to 010. This is due to the greater range of the extinction angles for the different varieties of felspar in sections parallel to 010 than for sections in other directions.[1] In some specimens from the Milngavie intrusions the felspars are zoned by inclusions.

The alteration of these felspars is a simple kaolinization in the more acid peripheries, but granules of calcite occur in the more basic kernels. Flecks of viriditic material are often to be found inside the felspar, indicating some degree of migration of the more mobile alteration products from the ferromagnesian minerals.

The *augite* is pale-brown, yellow, or almost colourless in the Kilsyth–Croy rocks, but in the Milngavie specimens there is often a faintly pleochroic purple tinge along the borders. A narrow twin lamellation confined to the centre of the crystal is prominent. In some of the coarser gabbroid varieties a basal striation occurs in a sahlite-like augite. In these rocks, also, the augite tends to occur in a long blady form elongated along the '**c**' axis.

In some sections it appears to take on to some extent the pleochroism and polarization colours of hypersthene, but not the straight extinction. The chemical analysis (*infra*) shows that the hypersthene molecule must be present to a large extent. This corresponds with the observations of Teall[2] and Elsden[3] on the augites of similar rocks from Northumberland and Pembrokeshire respectively.

The alteration of the augite is a process of considerable interest. The most common type is a peripheral change to brown hornblende.

[1] See Iddings, *Rock Minerals*, 1906, p. 229.
[2] Q.J.G.S., 1884; vol. xl, p. 648.
[3] Q.J.G.S., 1908, vol. lxiv, p. 286.

There is no sharply defined boundary with the augite, and irregular flecks of hornblende occur within the unaltered augite. In this change iron has been thrown out of combination, and reappears as secondary magnetite associated with the hornblende.

Green chloritic or 'viriditic' minerals are the product of another type of alteration. These are generally fibrous, with the fibres arranged in curved bundles or sheaves. They are highly pleochroic, the extremes of colour being straw-yellow and grass-green, or in a highly ferriferous variety from reddish brown to a dark green. This material certainly includes several varieties of chlorite, and is frequently intergrown with highly pleochroic brown biotite.

The basal striation occurring in the augites of the coarser rocks affords a starting-point for a distinct type of alteration. This occurs especially in the interior of a crystal, and consists of an accumulation of dusky granules of calcite arranged along the planes of the basal striation.

The final stage of both the hornblendic and chloritic types of alteration is the production of a pale-green serpentine uniformly sprinkled with specks of separated magnetite. The serpentine is slightly pleochroic, and is sometimes laminated. It is then frequently intergrown with brown hornblende. The bright polarization colours of augite are still retained in isolated areas, but the rest of the crystal possesses the aggregate polarization of serpentine. This type of alteration is well seen in the coarse rocks from Dumback, Fankerton, and Milngavie. In the latter rock the augite appears to pass directly into serpentine without intermediate stages. The serpentine makes its appearance along the cleavage and other cracks, leaving isolated areas of unaltered augite. Amphibolization is very rare in the Milngavie specimens.

In his study of similar rocks from the Bathgate Hills, Dr. Falconer[1] has arrived at the conclusion that amphibolization or chloritization of the augite occurs according as the alteration starts from the exterior or the interior of a crystal. There is nothing in the rocks under consideration to support this view. Both types of alteration appear to start indifferently from the exterior or interior of the crystal.

There is evidence for some local selective attack by weathering agents in the fact that alteration rarely occurs to the same extent in both felspar and augite. Where one is much altered the other is nearly or quite fresh, and vice versa. Thus, in a specimen from Barrwood Quarry, Kilsyth, the felspars are completely kaolinized, whereas, save for a slight peripheral amphibolization, the augite is quite fresh[2]; but in a rock from Nethercroy, about half a mile distant from the above locality, the felspars are quite fresh, whereas the augite is completely altered to a fibrous brown hornblende or to a greenish-brown serpentine.

An *orthorhombic* pyroxene occurs with the augite in some specimens, but is very sporadic in its occurrence. It occurs in prismatic, much cross-fractured, faintly tinted crystals, which in suitable sections

[1] Falconer, T.R.S.E., vol. xlv, pt. i, p. 141.

[2] Cf. Teall on the Corstorphine rock, *Brit. Petrog.*, 1888, p. 190.

show a distinct pleochroism from pale coppery red to a pale green. The crystals are rendered prominent by a marginal alteration to a deep-green, pleochroic, fibrous mineral, which probably bears the same relation to hypersthene as bastite does to enstatite.[1] The cracks also are broadly outlined by the same substance.

The abundant *iron-ore* offers some interesting features. It rarely occurs in other than skeleton crystals. Frequently it is in large, flat plates coating the faces of augite crystals. In one of the coarser varieties from Dumbuck Quarry, Croy, the thin cross-sections of plates are dispersed all over the slide, and all conform to one of three directions, at an angular distance of 120° from one another. The appearance is of a large, discontinuous, triangular framework of plates of iron-ore in which the other constituents have crystallized. The form of this framework shows that this mineral belongs to the ilmenite group. That it is titaniferous is put beyond doubt by the occurrence in some of the more altered rocks of grey leucoxenic decomposition products, and even yellow sphene.

Beside the regular skeletal form above described, there are other curious forms. One is radial like the spokes of a wheel, each spoke being knobbed at the extremity. There are also long saw-like serrated rods. Other types take the form of irregular, closely packed rods, the shape of the whole aggregate approaching to an idiomorphic form.

In addition to the constituents above described, a mesostasis always occurs in the interspaces. In the coarser and fresher rocks this material may be certainly identified as *micropegmatite*. It forms a regular intergrowth of rods of quartz and felspar, and where contiguous to a felspar crystal the felspar of the micropegmatite is continuous with it; and the wave of extinction occasioned by the chemical zoning of the felspar crystal starts in the micropegmatite. In a coarse rock from Fankerton, near Denny, minute triangular grains of quartz in regular rows are embedded in a ground-mass of decomposed felspar. The micropegmatite also occurs as parallel rods of quartz and felspar arranged perpendicular to the edges of felspar crystals. In a rock from a quarry near Dullatur the quartz and felspar rods are arranged radially and give an extinction-brush.

The micropegmatite is nearly always riddled with long needles of apatite. It also contains flecks of 'viriditic' minerals, and is frequently miarolitic. It has undoubtedly formed the channels whereby weathering agents have percolated through the rock, as evidenced by its own frequent decomposition and by the greater alteration of the minerals contiguous to it.[2] As the rock becomes finer in grain, the micropegmatite decreases in quantity and ceases to be identifiable as such. It appears as a greyish or reddish cryptocrystalline substance, riddled with apatite needles, filling up the interspaces between the other constituents.[3] In the basaltic contact-rocks micropegmatite disappears and olivine very rarely occurs.

[1] Teall, *Brit. Petrog.*, 1888, p. 192.
[2] Cf. Holland, Q.J.G.S., 1897, vol. liii, p. 411.
[3] Cf. Teall, Q.J.G.S., 1884, vol. xl, p. 644.

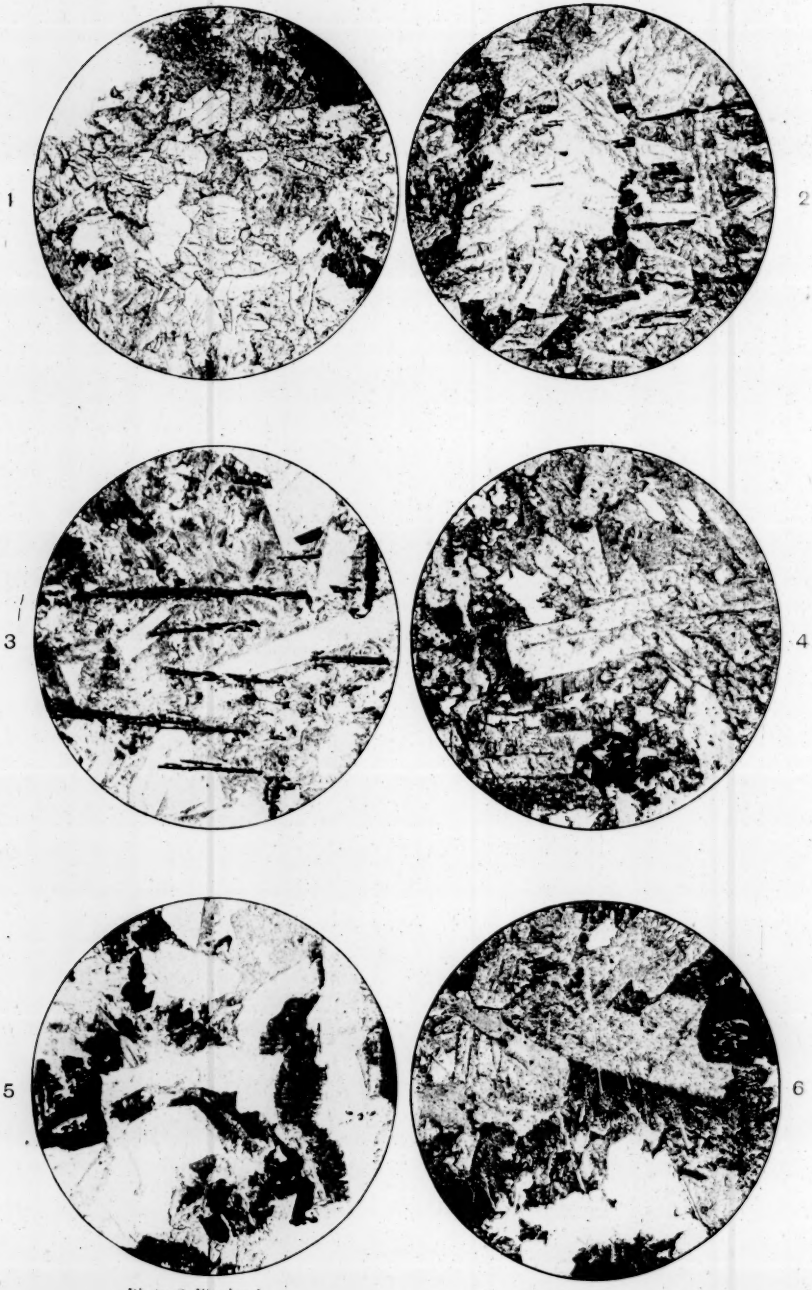

Photo. S. England.

Thin Sections of Granophyric Diabase from the Kilsyth–Croy District, Dumbartonshire.

The latter mineral is never found in this particular type of rock save at the extreme margin.

Irregular grains of *quartz* occur abundantly in the micropegmatite, even where it is freshest. This fact may be regarded as a presumption of primary origin. Considering how prone the micropegmatite is to decomposition, where it has formed the channels for the percolation of weathering agents and for the solutions depositing secondary substances, one would expect that the quartz, if secondary, would appear only where the micropegmatite is decomposed. The presumption of primary origin is strengthened by the occurrence in the quartz of projections and isolated fragments of micropegmatite, apatite, and granules of augite. This is specially well seen in the coarse pink rocks from Dumback and Fankerton quarries.

EXPLANATION OF PLATE XII.

Fig. 1. Granophyric Diabase, normal variety, Colzium Quarry. Ord. light; × 20. The upper half of the field shows a large turbid area of micropegmatite enclosing idiomorphic crystals of plagioclase and augite. The lower half shows a large plate of augite ophitically enclosing felspars. The clear space at the top left-hand is a want in the slide. The black areas are skeletal ilmenite. This slide represents the type that makes up the great mass of the sills and dykes.

Fig. 2. Granophyric Diabase, coarse var., Croy. Ord. light; × 7. Mostly plagioclase, micropegmatite, and ilmenite. Augite altered to serpentinous products. This slide shows the regular arrangement of the plates of ilmenite.

Fig. 3. Granophyric Diabase, coarse var., Dullatur. Ord. light; × 10. This slide also shows idiomorphic plagioclase and skeletal ilmenite embedded in a turbid micropegmatite ground-mass. The augite is altered to serpentinous products which do not appear very well in the photograph. The parallel arrangement of the ilmenite is well shown here also.

Fig. 4. Granophyric Diabase, Fankerton Quarry, near Denny. Ord. light; × 20. Felspar and augite in a turbid ground-mass of micropegmatite, which in places (left-centre of field) passes into clear areas of quartz. In the centre of the field the micropegmatite is composed of minute rods arranged perpendicularly to the idiomorphic felspar.

Fig. 5. Granophyric Diabase, Muchraw, Linlithgowshire. Ord. light; × 10. Clear felspar laths, curved blady augite crystals with 'herring-bone' structure accentuated by alteration, skeletal ilmenite and faintly turbid areas of micropegmatite (top of slide).

Fig. 6. Granophyric Diabase, Fankerton Quarry, Denny. Ord. light; × 20. Augite, turbid felspar, and still more turbid micropegmatite passing at the bottom of the photograph into a large area of quartz. All constituents enclose a great number of needles of apatite. The quartz encloses these and also isolated areas of micropegmatite, and is undoubtedly original.

I am indebted for these photographs to Mr. Samuel Fingland, the University photographer, Glasgow University.

(*To be concluded in our next.*)

III.—On a New Specimen of the Jurassic Ganoid Fish, *Pleuropholis lævissima*, Egerton.

By Miss Mary S. Johnston.

(PLATE XIII.)

HAVING in a collection of fossils from the Lithographic Stone of Bavaria a Ganoid fish, I consulted Dr. Smith Woodward, and through his kind assistance have proved it to belong to the rare species *Pleuropholis lævissima*. The species has hitherto been imperfectly known, the only figure being by Egerton of a comparatively small

fish, about the specific determination of which there seems to be some doubt. I therefore think the new specimen worthy of description, and it is shown of half the natural size in the accompanying figure. Nearly the whole of the fish is preserved in the fossil, but the head is shown only in impression. Most of the scales are removed from the near side, and the fins are fragmentary (see Plate XIII).

The length of the head, with opercular apparatus, is approximately equal to the maximum depth of the trunk, and contained six times in the total length of the fish. As shown in impression, the frontal region of the skull tapers rapidly to a point in front, where the mesethmoid forms a small expansion, which is as broad as long. The orbit is relatively large, and below it are traces of the bones of the jaws. Among these may be distinguished a part of the arched maxillary and impressions of some displaced fragments, bearing an ornament of fine ridges. The preoperculum widens rapidly downwards to the angle, where the small expansion is shown to be smooth, and below it are remains of broad branchiostegal rays, which are also smooth. The operculum and suboperculum are shown only in impression, but their outline is apparently complete. The operculum is slightly narrower above than below, where its maximum width exceeds two-thirds its depth. The suboperculum is about half as deep as broad, with the posterior inferior angle rounded.

The vertebral column is shown throughout the length of the fish at places where the scales are removed. Centra are seen, but they must have been only feebly ossified, perhaps in the form of rings, as they are very much flattened. Fragments of the ribs are conspicuous on the inner side of the scales, indicating that they also were feebly ossified, but were long and extended nearly to the ventral border. The column ends at the beginning of the caudal fin, where it is slightly upturned, with expanded hæmal spines below its extremity.

The form and proportions of the clavicular bones are not clearly seen, but their external surface is shown to be ornamented with fine vertical ridges. The rays of the paired fins are stout and flattened, with a relatively long, unjointed base and very finely divided distal end. In the remains of the pectoral fin the bases of the ten or twelve rays are widely spread. The pelvic fins, which are inserted just behind the anterior third of the trunk, are much smaller than the pectorals and consist of seven or eight rays, of which the finely divided distal ends are well preserved. The dorsal and anal fins are represented by the merest traces, but the caudal fin is sufficiently well preserved to show that it was forked and symmetrical. A few very slender fulcra are seen on the lower border of the caudal fin.

The scales, which completely cover the trunk, are thick and have a highly polished smooth enamelled surface. Nearly all those on the upper side of the fish have been lost, so that the less polished inner surface of the under scales is mostly seen. The principal scales are very finely serrated on their hinder margin. Their inner face is strengthened by a vertical, wide, flattened rib, which ends in a pointed peg above, and is hollowed at the lower end by a triangular socket for the peg of the next scale below. The excessively deepened flank-scales rapidly decrease in depth in the hinder half of the tail, where

Pleuropholis laevissima, Egerton. Lithographic Stone: Kelheim, Bavaria. Scale in inches.

all the scales are diamond-shaped and do not vary much in size. Above the deepened scales in the anterior half of the fish there appear to have been only two series of smaller scales, which are nearly square, being scarcely wider than deep, but on the ventral border there are at least four or five series of still smaller scales which are much wider than deep, united by a very large peg and socket and sometimes deeply crimped rather than serrated at the hinder border.

The principal lateral line clearly turns down one of the foremost deepened flank-scales, and is seen at many points throughout the length of the fish traversing the uppermost row of the small ventral scales. The presence of another slime canal in the normal position of the lateral line is indicated by a foramen on each alternate scale in the deepened flank-series.

The new fish now described is slightly larger than the type-specimen in the Munich Museum, and differs in the delicate serration of its scales. The latter character, however, is so difficult to observe that it may have been overlooked in the type; and the general agreement between the two specimens is so close that there cannot remain any doubt as to their specific identity.

EXPLANATION OF PLATE XIII.

Pleuropholis lævissima, Egerton: photograph of nearly complete fish, one-half nat. size. Lithographic Stone (Lower Kimmeridgian): Kelheim, Bavaria.

IV.—Wells of the North-Eastern Sudan.

By G. W. Grabham, M.A., F.G.S., Geologist to the Sudan Government.

(*Concluded from the June Number, p.* 271.)

THE necessity of providing a water supply for the town and harbour of Port Sudan has led to an investigation of the district, and some interesting water analyses, relating both to the Valley Fill and to the Maritime Plain, have been made. Through the kindness of Capt. Kennedy, R.E., Director of Public Works, and of Dr. Balfour, Director of the Wellcome Research Laboratories, I am able to quote some of them. The analyses are given on p. 318 and have been made, as indicated, either at the Chemical Research Laboratory, Khartoum, in charge of Dr. Beam (W.R.L., Khartoum), or by Mr. Lucas, Superintendent of the Egyptian Survey Department Laboratory, Cairo (S.D.L., Cairo). A rough map of the district (Fig. 2) shows the positions of the localities from which the samples were obtained.

The first six analyses relate to Khor Arbat: I, II, and III are from samples taken 21, 9, and 6½ miles respectively up-stream of the place where the valley debouches on to the Maritime Plain, and where the fourth sample was obtained. A steady increase is shown in the content of salts as the water passes down the valley. The first analysis is of a solitary sample, and waters containing as little or even less solids in solution have been obtained near the locality to which II relates. The other analyses are in each case selected from a large number, and may be regarded as typical.

The fifth analysis represents the composition of some flood-water that passed out of the valley. The figures are not as high as those

relating to the normal flow, but they show that even in its rapid passage a flood can pick up a considerable quantity of salts. During the flood the flow in the Valley Fill is in a direction away from the stream-bed, so that it does not appear possible that the salts could be derived through admixture with the normal underflow. Their presence can, however, be explained by the solution of the accumulation of salts formed on the surface of the ground through the evaporation

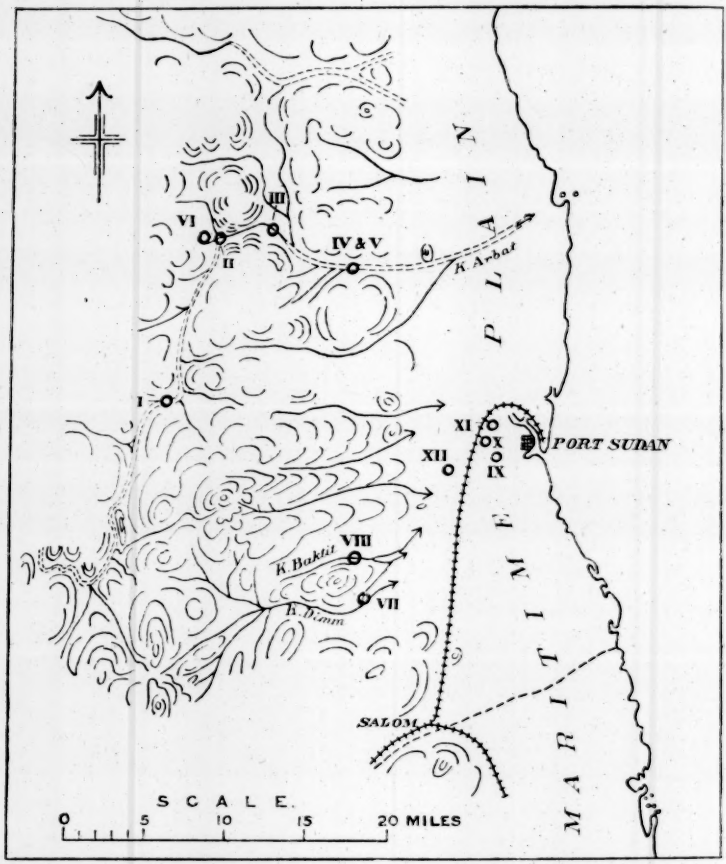

FIG. 2. Map of the vicinity of Port Sudan, showing the position of the localities to which the water analyses (on p. 318) relate.

of water raised by capillary action. This would also account for the resemblance that the proportions of the different constituents bear to one another in flood and normal flow. If such is the case, the quantities of salts should vary in a succession of floods, the later ones containing much less than the first, but figures are not available to test this.

Analysis VI shows the composition of a sample taken from a well at a distance of about 400 yards from the stream-bed, a little way

above the place where sample II was taken. The well-water contains rather more solids in solution, and is, as a rule, rather harder than the water from the stream-bed. The analysis of samples from this valley has extended over a period of about a year, and it has been found that the composition of the water is little subject to variation. Isolated samples, it is true, have given markedly different results, but these may be due to a variety of causes and do not affect the conclusion.

VII and VIII are analyses of water from wells in smaller valleys to the south-west of Port Sudan. They contain very much larger quantities of salts than those from Khor Arbat, and, as the drainage areas are composed of similar rocks, it appears that the difference in composition must in some way be due to their relative sizes. The smaller areas receive less rainfall and are more affected by evaporation.

The next three analyses are from wells on the seaward margin of the Maritime Plain, in the vicinity of Port Sudan and within about 2 miles of the sea. Though analyses IX and X show large quantities of salts, they do not represent such saline waters as those of the small rock valleys, while the composition of the sample from Bencini's well is quite comparable with the Khor Arbat analyses. Gypsum deposits do occur associated with those of the Maritime Plain, and, though none are known in the vicinity of these wells, perhaps the high content of sulphates may be accounted for in this way. The 'Far Well', to which the last analysis relates, is situated about 5 miles from the sea, and is intermediate in position between the rock valleys and the shore. It consists of two shafts with a gallery between them, and a constant quantity of water is pumped as a temporary supply for Port Sudan. The figures show rather a high content of chlorides as compared with the sulphates.

The analyses show that the underflow of the Maritime Plain is derived from sources widely different in quality. The underflow from the Valley Fill contains large quantities of salts, but it must be considerably diluted by the purer flood-water and local rainfall. It is therefore not surprising to find some of the wells near the sea yielding a less saline water than those of some of the rock valleys. A boring, made at a point about 1¼ miles south-west of the 'Far Well', traversed the deposits of the plain to a depth of 1100 feet. Both here and in the shallower boring at the 'Near Wells' it was found as a general rule that better water was obtained in the coarse-grained deposits than in the finer muds and sands. The quality also varies with the depth, and the best water is found at the surface of the zone of saturation. In the deep boring some improvement was found towards the limit of depth attained, but the quality of the water was not satisfactory, and the attempt to obtain a supply in this way was abandoned.

The deposits of the Maritime Plain are mainly submerged below sea-level, and the laws governing the flow of water in them offer an interesting problem, but at present the data are insufficient to enable us to discuss it. The greatest flow appears to occur on the surface of the zone of saturation where the best waters are found, but it does not seem possible to say how far the water beneath is to be regarded as stagnant. The rate of flow also depends on the nature of the deposits,

and, as these differ, the movement near the surface is not everywhere the same. The striking differences in composition shown by analyses IX, X, and XI, all relating to wells within about 2 miles of the sea, may be accounted for partly by the extents to which the different wells are used, and partly by the nature of the deposits from which the water is derived, whether fine or coarse grained. I have not visited these wells, but I understand that both those of Bencini and Simon Lingo are in 'conglomerate', and that the 'Far Well' is in similar material. The general opinion is that the best water is derived from this 'conglomerate' as opposed to the finer-grained beds. The concentration of salts in finer-grained deposits appears to be a phenomenon of fairly common occurrence, and some of the principles developed by Mr. E. C. Sullivan[1] in connection with the deposition of ore may account for it, but my knowledge of his work is at present only derived from a review kindly shown me by my colleague Mr. Dunn. It is pointed out that if a solution is filtered through a soil the first part of the filtrate is less saline than the original solution, a proportion of the salt remaining behind in the filtering medium. The effect increases with the fineness of grain of the filtering medium, and appears to be due to the different rates of diffusion of the constituents of the solution. This principle would account for the existence of more saline waters in the finer-grained parts of a deposit, and suggests the possibility of these being obtained when the normal underflow is disturbed by a well.

The existence of wells such as Bencini's, yielding a comparatively good water, has led to attempts at obtaining larger supplies by means of pumping. This implies deeper wells, greater lowering of the water-table, and, in consequence, a more saline water is yielded. The analysis of a sample taken from this well in April, 1908, showed only 318 parts per million of solids in solution (W.R.L., Khartoum), while in samples taken since that to which analysis XI relates, and collected after periods of bailing, the quantity was found to have increased to 1110 parts. A sample from Simon Lingo's well, taken in September, 1908, showed 1440 parts of solids per million (W.R.L., Khartoum), but, as a result of deepening and increased pumping, the water became more saline, and was found to contain, as shown in the accompanying table, no less than 2573 parts of solids, and this only a month after the former sample was taken. The 'Far Well' is said to have yielded a better water at first, but, as a result of continual pumping, the water has become more saline, and now appears to maintain approximately the composition shown in the analysis.

Capt. H. H. Kelly, R.E., to whom I am indebted for much of the information about the wells in the neighbourhood of Port Sudan, considers that, in some cases at least, the wells are of considerable antiquity. They have evidently been made by people with a knowledge of construction that the present natives, the Hadendoas, do not possess, and his discovery of a Roman coin in one of the khors where these wells are situated in a measure confirms his conclusion.

Before leaving this area, where the detrital deposits of the Valley

[1] U.S.G.S. Bull. No. 312, 1907.

Fill and Coastal Plain play such an important part in the water-supply conditions, reference must be made to the arid regions of North America, which supply examples of similar conditions. These have been described by Mr. F. H. Newell,[1] and the underground waters of the Salt River Valley have since been fully dealt with by Mr. Willis Lee.[2] The Salt River Valley is partly filled with alluvial deposits carrying a large amount of underflow. The valley is much wider than any among the Red Sea Hills, and, as the surface stream-bed has wandered over it in times of flood, filling up the valley, it has left its trace among the finer deposits in the form of boulder-beds and gravels. These boulder-beds have been found to yield the best supplies of water. This, too, is fairly rich in salts, and the town supplies of Phœnix and Tempe both contain over 1000 parts per million of solids in solution, while some with over 3000 parts is successfully used for irrigation. In the light of this we may look forward to a day when the underflow of the Maritime Plain will be utilized in the same way, and more data will be available for the discussion of the problems connected with it. At present there are gardens at Shata, near Suakin, and small cultivated plots near Port Sudan that show the possibility of using the water in this way.

Wells in the Nubian Sandstone Series.

In sandstone regions the wells are no longer dependent on local condition for their water supply. Most of it is probably seepage from the river, and perhaps some comes from distant areas of greater rainfall, but, provided the sandstone is deep enough to contain the water-table, there is no difficulty in obtaining a supply by means of wells. The importance of this series has long been recognized as affording supplies of water, and in Egypt these are tapped in several oases, where the water rises under hydrostatic pressure from beneath the overlying beds. In the part of the Sudan under consideration the sandstone is found near the Nile and extends from a little way south of Khartoum to Wadi Halfa, where it passes beyond the area. In Egypt the Nubian Sandstone Series is overlain by younger beds, and, though these have been found to occur much further south than it was formerly supposed,[3] they have not yet been discovered in the Sudan.

Towards the south, in many places where grazing is good, the natives have wells in the sandstone. These, frequently 200 feet and sometimes even 300 feet in depth, have been dug by them with the primitive tools at their disposal. The presence of Cotton Soil, though it may prevent the local rainfall reaching the water-table, naturally does not interfere with the well supplies.

The arid regions to the north afford no grazing, and the wells are far apart even on the caravan routes. These generally appear to be situated in hollows beneath the general level of the country, where the water-table is within a few feet of the surface, and have thus been readily found by the natives. Selima Oasis[4] is probably an example

[1] U.S.G.S., Twelfth Annual Report, 1891, p. 215.

[2] U.S.G.S., Water Supply and Irrigation Paper, 1905, No. 136.

[3] W. F. Hume, *Cairo Scientific Journal*, 1908, vol. ii, p. 321.

[4] See Mr. J. Currie's description [quoted], *Anglo-Egyptian Sudan*, Wymans, London, 1905, vol. i, p. 203.

of this, and, though Capt. Lyons[1] has suggested that its existence is related to folding, I do not see that this would affect the level of the water-table unless the clay beds in the series are more extensive than is supposed.

The construction of the railway from Halfa to Abu Hamed led to well digging in the Nubian Desert, and Mr. Dunn tells me that good supplies are obtained in the sandstone at a depth of about 100 feet at No. 4 and No. 6 stations. The famous Murrat wells, close by, have not yet been visited by geologists, but from other accounts they appear to draw their water from Valley Fill among crystalline rocks, and are perhaps just outside the sandstone area. If necessity arises, I have no doubt that successful wells could be made all over this arid sandstone area, both east and west of the Nile, and in many cases, like those already made on the railway, the water would be found at no great depth below the surface.

The composition of the waters may be illustrated by the following analyses which have been published by Mr. Lucas[2]:—

Analyses expressed in parts per Million.

	I.	II.	III.	IV.
Solids in solution	1712·0	1136·0	668·0	292·0
Chlorine	292·2	83·3	72·0	31·2
Sulphuric anhydride	563·0	301·7	122·1	43·9
Lime	166·0	230·0	124·0	74·0
Magnesia	103·2	61·6	65·2	21·7
Sodium carbonate (*a*)	*nil*	42·4	68·9	*nil*
Sodium bicarbonate (*b*)	302·4	193·2	344·4	210·0

(*a*) Alkalinity to phenolphthalein calculated as sodium carbonate.
(*b*) Alkalinity to methyl orange, less that due to sodium carbonate, calculated as sodium bicarbonate.

I. No. 6 Station. Contains also SiO_2 27·2, Fe_2O_3, and Al_2O_3 13·2.
II. Bir Adiela.
III. Selima Oasis, north well.
IV. Selima Oasis, west well.

From these figures it appears that the waters vary considerably in the amounts of salts they contain, but they all show a good deal of alkalinity. At Selima there are deposits of salt extensive enough to be worked by the natives. The presence of water so close to the surface must lead to a large accumulation of salts by the evaporation of moisture drawn up by capillary action. A marsh is said to exist now, and, no doubt, a small rise in the level of the water-table would convert this into a lake; sheets of water would also appear in other places where only shallow wells exist now. Evaporation would soon concentrate the salts, and it is quite possible that deposits may have been formed in this way. Travellers have reported many bitter wells in the vicinity, and it is not surprising that these waters, in most cases, contain larger quantities of salts than do the artesian ones of Kharga, in which the quantity ranges from 430 to 470 parts per million.[3]

Another point of interest is the presence of large quantities of nitrates in some of these waters. A sample from Nahud, analysed by Dr. Beam, was found to contain no less than 6·5 grams per litre

[1] Q.J.G.S., 1894, vol. l, p. 539.
[2] *Chemistry of the River Nile*, Cairo, 1908, pp. 72, 74.
[3] H. J. L. Beadnell, Geol. Mag., 1908, p. 105.

of nitre, or nearly an ounce to the gallon.[1] The reduction of these nitrates, for instance by iron pyrites, would account for the large amount of nitrogen gas found in the artesian waters of Kharga.

The origin of the water in the sandstone is too extensive a subject to be entered into here. The bulk of the water, at any rate within the area dealt with here, is probably supplied by seepage from the river. This takes place, for the most part, during the flood when the Nile is high and the rapidly flowing current is keeping the pores of the bed freely open. It does not appear that the Nubian Sandstone extends much further south than the limits shown in Rolland's map.[2] The small amount of rainfall occurs in violent storms of short duration, and provided the water forms rapidly flowing streams, the proportion soaking into the ground must be very large. Often it remains in pools, or is retained by the surface soil so that it evaporates away without adding to the underground water.

Concluding Remarks.

There are some special cases of well supplies that do not fall among the classes already described, but call for some notice.

For some time after the rains, water can be obtained from shallow holes made in the sandy beds of khors, but later it either evaporates or percolates away, and seldom lasts until the following rainy season. The occurrence of water in this way presents a curious problem, for in some cases at least, if not in all, there is no impermeable substratum to hold it up; yet there it remains, while the permanent ground water-level may be a hundred feet below. This phenomenon is not limited to sandstone regions, but may occur on the surface of the Valley Fill. As an example the wells in Wadi Mugaddam may be cited. Here the natives find water close to the surface immediately after the rainy season. They deepen the wells as the water falls, but finally it disappears and they have recourse to deep wells in the sandstone. I saw another instance of a similar thing in a small valley half-way between Khartoum and Wadi Mugaddam. The water had been obtained from shallow holes in the stream-bed for some time after the rains, but when I was there a few months later there was no water in a well over a hundred feet deep in the sandstone close by.

Another special case of well supplies is found connected with Khor Gash. In summer this stream comes down in flood from the mountains of Eritrea and loses itself on the plains north of Kassala, and during the rest of the year good supplies of water are obtained in the stream-bed, but the permeable material is not extensive alongside. The case is really analogous to the Valley Fill, with impervious soil taking the place of crystalline rock. The ground around is either alluvial or Cotton Soil, and wells at a distance from the stream-bed have penetrated to a considerable depth without obtaining any water. I am told that the natives have a fairly shrewd idea of the limits within which water is to be found, and these, no doubt, depend on the extent the stream-bed has wandered before assuming its present course.

Large supplies of water are derived from wells in the alluvial deposits alongside the Nile, but these call for no special notice here.

[1] Wellcome Research Laboratories, Khartoum, Third Report, 1908, p. 397.

[2] Reproduced in E. Suess, *La Face de la Terre*, vol. i, p. 259.

ANALYSES EXPRESSED IN PARTS PER MILLION.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Solids in solution	820·0	952·0	968·0	1156·0	696·0	1096·0	3051·0	2992·0	2604·0	2573·0	1034·0	1506·0
Chlorine	211·3	246·5	270·8	343·7	166·7	298·6	1143·1	1247·7	767·3	999·6	179·7	528·8
Chlorine as sodium chloride	348·5	406·7	446·8	567·1	275·0	492·7	1885·7	2058·3	1266·1	1649·0	296·5	872·3
Sulphuric anhydride	93·7	115·3	122·2	144·1	68·8	131·3	375·8	217·5	559·3	420·8	180·6	175·8
Lime	127·3	150·4	132·1	166·8	—	172·2	47·4	245·3	243·8	241·1	173·2	133·8
Magnesia	21·1	42·4	44·3	50·7	—	51·7	42·5	151·3	99·1	96·0	36·2	48·0
Temporary hardness, parts per 100,000	17·0	—	18·0	16·4	24·4	22·8	—	—	15·5	—	—	—
Permanent hardness, parts per 100,000	14·3	—	14·4	23·9	—	18·1	—	—	48·3	—	—	—
Date of sample	—	Sept. 08	Sept. 08	Sept. 08	Aug. 08	Sept. 08	Oct. 08	Oct. 08	Mar. 08	Oct. 08	Aug. 08	Oct. 08

I. Water, 21 miles up-stream from mouth of rock valley, Khor Arbat. S.D.L., Cairo.
II. Stream, 9 miles up-stream from mouth of rock valley, Khor Arbat. S.D.L., Cairo.
III. Stream, 6½ miles up-stream from mouth of rock valley, Khor Arbat. S.D.L., Cairo.
IV. Well in Valley Fill, mouth of rock valley, Khor Arbat. S.D.L., Cairo.
V. Flood, sample taken at mouth of rock valley, Khor Arbat. S.D.L., Cairo.
VI. Well in Valley Fill about 400 yards from bed of stream a little above point where sample II was taken. S.D.L., Cairo.
VII. Arab well, Khor Dimm, 14 miles S.W. of Port Sudan. W.R.L., Khartoum.
VIII. Arab well, Khor Baktit, W.S.W. of Port Sudan. W.R.L., Khartoum.
IX. "Near Wells," about 2 miles S.W. of Port Sudan. S.D.L., Cairo.
X. Simon Lingo's well, about 2 miles W. of Port Sudan. W.R.L., Khartoum.
XI. Bencini's well, about 2 miles N.W. of Port Sudan. W.R.L., Khartoum.
XII. "Far Well," about 5 miles W.S.W. of Port Sudan. W.R.L., Khartoum.

REVIEWS.

I.—The San Francisco Earthquake.

The California Earthquake of April 18, 1906: Report of the State Earthquake Investigation Committee. By Andrew C. Lawson, in collaboration with G. K. Gilbert, H. F. Reid, and others. Carnegie Institution of Washington.

THREE days after the earthquake which destroyed so large a part of San Francisco in 1906, a committee was appointed by the Governor of California for the purpose of investigating the different phenomena, both transitory and permanent. The committee included Professor A. C. Lawson as chairman and several well-known men of science. Working in conjunction with them were also many other observers, who investigated various details and examined the whole of the ground traversed by the great fault, and photographed and measured the displacements of the surface-beds. By the end of the year the materials were nearly all collected, and the results of the discussion when completed will fill two quarto volumes and a folio of maps and plates. Of these the first volume and the atlas are already published. The former contains the record of the facts observed, the detailed account of the fault and of the movements along it which caused the earthquake, the description of the secondary phenomena and of the variations of intensity throughout the disturbed area. The second volume will be occupied by an investigation of the seismographic records of the earthquake obtained at observatories in all parts of the world. The theory of the seismograph will also be considered in some detail. In the atlas the course of the fault is clearly traced, the variations of intensity in the shock are depicted, especially within the city of San Francisco, and the seismograms from nearly seventy observatories are reproduced. In addition to the forty plates in the atlas there are more than three times that number in the first volume, chiefly reproductions of photographs. The report is published by the Carnegie Institution of Washington, and it is evident that no expense and no trouble on their part have been spared to make it the most complete account ever furnished of any scientific phenomenon. Nor have Professor Lawson and his colleagues failed in any way to take advantage of so unique an opportunity. Their work has been admirably done. The immense mass of detail is carefully collated. Whenever possible the editor has allowed the observers to speak for themselves in short notes and papers, which are so neatly inserted that in reading the text there seems to be no breach of continuity.

The advantages of this mode of collaboration are nowhere better illustrated than in the description of the remarkable fault which occupies so large a part of the first volume. The fault was traced by different observers for a distance of at least 190 miles, except for a few short interruptions in which its course is submarine, and there can be little doubt that it reappears after a somewhat longer break still farther to the north, so that the total length of the line is about 270 miles. On the whole, the path of the fault is a slightly curved line running in a general north-west and south-east direction, and, to the north of San Francisco, keeping close to the Californian coast. Its

mere length is not, however, its most remarkable feature. Throughout its whole extent there was a sudden displacement of the crust, the ground on the south-west side to a great but unknown depth being shifted to the north-west, and that on the north-east side to the south-east. The amount of the horizontal displacement varies considerably. As a rule it lies between 8 and 15 feet, and in no place exceeds 21 feet. All structures which crossed the line of the fault were severed. Roads and paths were displaced, sometimes by as much as their own width or more, fences were snapped across and their ends separated, piers were broken and shifted, and water-mains ruptured and telescoped. These and other effects are fully illustrated by numerous photographs. In other earthquakes there have been more pronounced changes of elevation along the fault, but in no other known case have the horizontal movements been so persistent over so vast an area. In none, certainly, have the fault-movements been so carefully studied or the investigations of the geologist been aided so effectively by the researches of the biologist and the measurements of the surveyor.

Among the minor sections of the report one of the most useful is that which deals with the relations between the nature of the ground and the intensity of the shock. The distribution of the damage in San Francisco affords decisive evidence on this point. Though the area covered by the city lies only a few miles from the fault, the intensity of the shock was governed more by the nature of the underlying rock or soil than by proximity to the fault. In houses built on rocky ground, especially on the summits of hills, many chimneys remained unshattered; on thick deposits of sand or earth, brick walls were badly cracked and chimneys were generally destroyed; on 'made' land, and most of all on that which occupies the sites of recently filled creeks and marshes, ordinary buildings collapsed and even the best masonry was seriously injured. The lesson conveyed could not be more clearly enforced; yet it is one to which the rebuilders of San Francisco are not paying all the attention which it claims.

The only omission of any consequence in the book is the absence of comparisons drawn between the phenomena of this and other great earthquakes. If the San Francisco earthquake were the only shock known to mankind, the attention paid to it could hardly have been more exclusive. The examination of the points in which the Californian fault resembles, or differs from, those of other earthquakes might with advantage have been more detailed. The scantily observed sound is described, but no surprise is expressed at its general inaudibility. The valuable discussion on the distribution of damage in San Francisco would have received ampler illustration if it had been pointed out that similar relations between the amount of damage and the nature of the ground have been noticed in many other earthquakes. But comparisons such as these would have increased the size of volumes already large enough and have delayed their publication. They can be suggested by other writers, and there can be little doubt that in this report there are facts described and photographs reproduced that will form a veritable mine for workers in nearly every branch of seismology.

C. Davison.

II.—The Stone Ages in North Britain and Ireland. By the Rev. Frederick Smith; with an Introduction by Augustus H. Keane, LL.D. 8vo; pp. xxiv, 377, with 521 illustrations. London: Blackie and Son, 1909. Price 16*s.* net.

FORTIFIED with an introduction from Dr. A. H. Keane, late Vice-President of the Royal Anthropological Institute, the Rev. Frederick Smith has in the volume before us brought forward the results of observation and diligent collecting carried on during a period of nearly forty years. According to Dr. Keane, the author "opens a new and wider chapter in the history of early man by extending the inquiry to the whole of the British Isles and producing for the first time convincing evidence that both Scotland and Ireland were inhabited during the old Stone Age. His claim to have established this fact, against the inveterate prejudice and incredulity even of the most advanced British specialists, lies open before us and demands a hearing". With this latter appeal we are prepared cordially to agree. When, however, Dr. Keane draws attention to the fact that implements of Palæolithic type have been discovered in so many regions of the earth, from South Africa to Korea and South America, and asks what was to prevent primitive man from crossing the border and ranging over North Britain, we turn to the illustrations in this book and are surprised to find not a single characteristic type of Palæolithic implement among the figures that illustrate the Scottish and Irish specimens which Mr. Smith has gathered in situ. What may be regarded as the best example is an implement of flint or agate which was picked up in the bed of the Esk.

The specimens on which Mr. Smith relies are profusely illustrated, and they are undoubtedly of importance as representing a peculiar and persistent type. As the author remarks, Dr. Keane "agreed with me that Nature works miracles if the constant repetition in form and design which groups of the other specimens exhibit were the result of accident and not of human intention". The same remarks apply to Eolithic implements. Single specimens, or a few only, may fail to convince, but a study of the series accumulated by Dr. H. P. Blackmore, Mr. Benjamin Harrison, and others, would impress, if it did not convince, any candid inquirer.

The Scottish specimens collected and illustrated by Mr. Smith have been formed from a variety of rocks, such as basalts, granites, quartzite, dolomitic limestone, and ironstone. Many have been water-worn, others have suffered from weathering which has produced "a kind of mellowing of surface". The forms appear largely to be due to the character of the materials at command, to their texture, and natural jointing and fracture; and the author denies that "the relics of Palæolithic man in Scotland ought to be, and must be, replicas, in form and style of work, of the typical flints".

Many of the specimens which he has collected were found on the seashore or along the beds of rivers. More important are those found in situ in beds of valley gravel and in glacial drift. We cannot in all cases agree with his identification of Boulder-clay, as for instance on p. 90, where on Almond-side, Perth, the deposit is described as "largely sand and gravel highly rolled, with large erratics from one

to several hundred-weights here and there in the mass". Evidence, however, is given of the occurrence of glaciated specimens at Crieff, and the discovery induced the author to read a paper on "Evidences of Palæolithic Man in Scotland" at the meeting of the British Association at Edinburgh in 1892, and, as he remarks, "the approach to that great Society was the reverse of encouraging." As a rule, the specimens brought forward by Mr. Smith exhibit no evidence of chipping or flaking, but rather give the idea that the stones are mostly natural in shape but modified by rubbing and polishing until they have assumed a serviceable form. Large examples are mentioned from 10 to 17 inches in length and occasionally weighing as much as 20 lb. A scale of size attached to each figure would have been useful. Among the 'Domestic Forms' are pebbles simply broken, with flat, smoothed surfaces, and other more roughly shaped stones with similar surfaces. These implements are grouped as Palæolithic 'flat-irons'. We have seen broken flint-pebbles with polished ends from the Cannon-shot gravels of Mousehold, Norwich, where a number were collected by Mr. J. T. Hotblack. They may have been utilized as rubbers or pounders. The author figures sundry forms of implements with handles which may have been serviceable as choppers or knives, and others that would appear to have been fashioned after the shape of bones or jaws, one example being referred to as likely to "have done as good service in the hands of Samson as the historic ass's jaw-bone". Some specimens are described as "chisel-like and broad-edged and bell-shaped polished axes" of Neolithic type, and yet of great antiquity, suggesting that there was no great void in time between the epochs of Palæolithic and Neolithic Man.

The author writes with enthusiasm, but at times with a confidence that is not justified, as for instance when he refers to glaciated flints from the Thames gravel at Datchet. In drawing attention to the many specimens he has gathered in Scotland and to the remarkably similar forms he has obtained in Ireland, he has done a service to students of Prehistoric Archæology. Others will be stimulated to investigate the subject. The absence of an index is a serious drawback to the utility of the volume.

III.—Brief Notices.

The New Zealand Geological Survey has issued a memoir on "The Geology of the Cromwell Subdivision, Western Otago Division", 1908, by Mr. James Park, Professor of Mining and Mining Geology in the University of Otago. The country dealt with is a mountainous one, rising to heights ranging from 4000 to 7600 feet on the borders of the mountain plateaux, while the valleys are mostly narrow rocky defiles. The county town, Cromwell, with about 600 inhabitants, is situated on a river terrace at the junction of the Clutha and Kawarau Rivers. The prevailing rocks are mica-schists, most probably belonging to altered Palæozoic formations; they contain bands of chlorite schist, which are regarded as altered contemporary volcanic rocks, and also a dyke of serpentine. In the Cromwell basin there is a great thickness of Pliocene freshwater beds, with seams of lignite of great economic value. Following this

lacustrine series there is a great assemblage of fluviatile and glacial drifts, ranging in age from the close of the Pliocene to recent times. All the gravels and glacier detritus are gold-bearing, and most of them have been worked with profit. There are two great systems of lodes in the mica-schists in which gold has been worked, but vein-mining has now ceased. Full particulars are, however, given of the workings. Accounts are also given of silver, antimony, asbestos, graphite, lignite ('coal'), and of water-supply. The memoir is divided into sections dealing with the physiography, general geology, economic geology, and petrography.

The University of Durham Philosophical Society has published as Memoir No. 1, an essay "On a case of Thrust- and Crush-brecciation in the Magnesian Limestone, County Durham", by Dr. D. Woolacott, F.G.S. It is illustrated with 2 plans, 20 photographs, and 4 text-figures. The substance of the essay was brought last year before the British Association at Dublin, and the abstract giving the author's conclusions was published in the Geological Magazine for October.

Earth Tides.—In an article on Earth Tides (*Morning Post*, Feb. 23, 1909), it is stated that Professor Hecker, of Potsdam, has arrived at the conclusion that "this apparently solid earth is subject to daily oscillations analogous to the tides, rising and falling twice in every twenty-four hours some twenty centimetres, or about eight inches". It is further stated that independent investigations which have been made in the observatory at Kimberley indicate that there is a gradual rise and fall in the earth's crust of more than 8 inches once daily, a movement attributed to the sun's influence, but not regarded as tidal. It is also mentioned that South Africa has a tilt to the east in summer and to the west in winter.

The Rhodesian Miner's Handbook. By F. P. Mennell, F.G.S. pp. vi, 167. Bulawayo: Ellis Allen, 1909. 2nd edition. Price 5*s*.

In the Geological Magazine for November, 1908, p. 519, we called attention to this publication, and commended it as a sound and practical guide. We are glad to find that a new edition has been called for, enabling the author to bring his useful work well up to date and to supplement it with further information regarding the mines and mining prospects.

Mineral Discoveries in the Northern Territory of South Australia.—Mr. H. Y. L. Brown, Government Geologist of South Australia, has issued a report on recent mineral discoveries and further boring operations in the northern territory. Copper-ore has been discovered in a granitic area at Mount Davis Creek, in the Pine Creek District; and tin-ore and gold have also been found in new localities in the same district. Information is given of the borings for gold at Pine Creek and Fountain Head; also of borings for coal at Port Keats and Cape Ford, which were carried to depths of 1505 and 1506 feet. No payable coal-seams were encountered; but at Cape Ford, at 1050 feet, fresh water was struck and it rose to the surface, and the yield at 1374 feet was 1600 gallons per hour.

"The Formation of Geodes, with remarks on the Silicification of Fossils," is the subject of a paper by Mr. Ray S. Bassler (Proc. U.S.

Nat. Museum, 1908, vol. xxxv, pp. 133–54, with seven plates). After some general remarks on geodic cavities which are common in all kinds of rock, the author refers more particularly to those in limestones and shales, and to the Niagara limestone of Lockport, which is rich in examples. There the cavities in many cases are due to the removal by solution of fossils, or they may be fractures in the strata enlarged by the expanding force of crystallization; the mineral matter lining the cavities is usually dolomite, gypsum, and calcite. Frequently fossils themselves, such as Brachiopoda, furnish the cavities and are lined with crystalline material. The most striking geodes are those of siliceous composition, which occur usually in shaly, fossiliferous strata. The author remarks that "fossils lying in the path of surface-waters are subject to a complete replacement of their substance by silica; when crushed or fractured, fossils may have the breaks lined with a siliceous deposit. In the latter case, continued deposition and the expansive force of the crystals will result in a hollow, rounded mass or geode, lined with inwardly pointing crystals, and on the outside covered with remnants of the fossil". In the well-known Keokuk geode-bed which occurs in the Knobstone division of the Lower Carboniferous at Keokuk, Iowa, the geodes are not disseminated along the planes of stratification, but they lie on the edge or close to joint planes or rifts in the strata through which water had easy access. Elsewhere they occur in the surface-soil and in the beds of streams. Most of them appear to have been formed in the way above mentioned, and to have originated from Crinoids and Brachiopods.

Vegetation of British Peat Mosses.—"The Changes in the Vegetation of British Peat Mosses since the Pleistocene Period" is the title of a paper by Mr. F. J. Lewis (Proc. Liverpool Geol. Assoc., New Series, No. 3, November, 1908). The observations are here confined to Scottish peat mosses from the Southern Uplands to Skye, the Outer Hebrides, and Shetland. The deposits are grouped as First (Lowest) Arctic Bed, Lower Forest, Second Arctic Bed, and Upper Forest. Concerning these the author remarks "that the first Arctic bed contains an Arctic-Alpine flora, which existed over wide areas near sea-level, and this is succeeded first by forest with temperate plants, which in turn yields place to a second Arctic-Alpine association. These successive strata indicate a definite sequence of events taking place simultaneously over the whole of Britain". The Upper Forest is not met with beyond the mainland of Scotland, and in areas examined in the Grampians and in Assynt the deposits comprise two zones, separated by peat with remains of Arctic birch and willow. In the south of Scotland the Upper Forest consists for the most part of Scotch pine. In his concluding remarks the author finds it difficult to reconcile these several stages in the peat with the theory of a single glaciation, as they suggest considerable oscillations in climatic conditions, and agree closely with the scheme of classification proposed by Professor James Geikie. Remnants of local ice-sheets and glaciers may have existed in the mountains when the earlier beds were laid down, and it would have been better if the author had used the word "during" instead of "since the Pleistocene period" in the title of his paper.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—*May* 12, 1909.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, and afterwards Dr. J. J. H. Teall, M.A., F.R.S., Vice-President, in the Chair.

The following communications were read:—

1. "The Hartfell–Valentian Succession around Plynlimon and Pont Erwyd (North Cardiganshire)." By Owen Thomas Jones, M.A., B.Sc., F.G.S.

In this paper the author deals with the stratigraphical succession and the geological structure of an area of about 40 square miles, lying in the hilly district about 12 to 16 miles east of Aberystwyth. In an historical introduction the work of previous observers, including Sedgwick, Ramsay, and Walter Keeping, is dealt with.

The rocks within the district are divided into three stages, which are further subdivided into groups and zones, as follows:—

VALENTIAN.	C. Ystwyth Stage.	(*c*) Rhuddnant Group.	2. Rhuddnant Grits.	
			1. Rhuddnant Shales.	
		(*b*) Myherin Group.	2. Blaen Myherin Mudstones.	
			1. Dolwen Mudstones.	
		(*a*) Devil's Bridge Group.	Mudstones with thin grit-bands.	
	B. Pont Erwyd Stage.	(*c*) Castell Group.	3. Flags and shales. (Zone of *Monograptus Sedgwicki.*)	
			2. Shales and mudstones. (Zone of *Cephalograptus cometa.*)	
			1. Mudstones and shales. (Zone of *Monograptus convolutus.*)	
		(*b*) Rheidol Group.	4. Black shales and mudstones. (Zone of *Monograptus communis.*)	δ. *Leptotheca*-band.
				γ. *Magnus*-band.
				β. *Triangulatus*-band.
				α. *Triangulatus*-var. band.
			3. Flags and black shales. (Zone of *Monograptus cyphus*, s.s.)	
			2. Flags with thin shales. (Zone of *Monograptus*, sp. nov.)	
			1. Flags and shales. (Zone of *Monograptus*, sp. nov.)	
		(*a*) Eisteddfa Group.	2. Flags, shales, and grits. (Zone of *Cephalograptus? acuminatus.*)	
			1. Flags with thin shales. (Zone of *Glyptograptus persculptus.*)	
HARTFELL.	A. Plynlimon Stage.	(*c*) Brynglâs Group.	Mudstones.	
		(*b*) Drosgol Group.	Grits, conglomerates, and mudstones.	
		(*a*) Nant-y-moch Group.	Flags with thin shales. (Zone of *Dicellograptus anceps.*)	

The Plynlimon Stage is developed in the northern part of the district, between Plynlimon and Pont Erwyd; the Pont Erwyd Stage along the two valleys of the Rheidol and the Castell, which converge near Pont Erwyd village; while the Ystwyth Stage is developed on the

plateau-like tract extending from the Castell Valley to the Ystwyth Valley.

The stratigraphical succession is demonstrated by a series of sections and traverses across various parts of the district, and lists of fossils (mainly graptolites) collected from the various zones are given. The palæontological evidence is in entire accord with the stratigraphical evidence.

The structure shows many points of interest, and is clearly brought out by the mapping. Three types are dealt with — (1) folding, (2) strike-faulting, and (3) normal faulting; but the first is predominant.

The rocks are folded into a primary anticlinal fold or anticlinorium, with a southerly 'pitch' of 10° to 15°. This primary fold is composed of a number of secondary folds of a symmetrical type, with axes ranging nearly due north and south and pitching as above. Occasionally the secondary folds are complicated by smaller folds or crumplings. The effect of the plication structure on the rock-outcrops, and especially on the topographical features, is dealt with in some detail. The latter are shown to be dependent in an important degree upon the pitch, and to a much smaller degree upon the dip of the rocks.

Strike-faults play a minor rôle in the structure, and their effects are of little importance; they have not been observed to carry mineral deposits.

The normal faults of the district are of greater interest. They range in an east-north-easterly direction, and nearly always carry sulphidic ores of lead, zinc, or copper. They appear to be quite independent of the folding, and behave generally as if they were of later date.

A brief account is given of the district lying on the western limb of the anticlinorium between Pont Erwyd, Devil's Bridge, and Aberystwyth. Evidence is given for assigning to the 'Aberystwyth Grits' of earlier observers a position much higher in the geological sequence than has hitherto been attributed to these 'Grits'.

The paper concludes with a tabular list of fossils, correlation tables, and a description of two species of graptolites of zonal importance.

2. "The Geology of the Neighbourhood of Seaford (Sussex)." By James Vincent Elsden, B.Sc., F.G.S.

This paper illustrates the application of zonal methods to field-geology in a Chalk area. It deals with a portion of the South Downs lying between Eastbourne and Newhaven. The inland outcrops of the uppermost zones of the Chalk are mapped. In tracing the boundary-lines fossil evidence is alone relied upon, lithological characters being found untrustworthy. Certain structural features of this area are thus brought to light and discussed.

On the east of the Cuckmere River the beds examined are found to be nearly horizontal. On the west side they are bent into a sharp uniclinal fold, striking east and west. Seaford Head represented a remnant of this fold, the westerly extension of which is destroyed by marine erosion. The low ground between Seaford and Chyngton occupies the trough of the fold, from which dip-slopes rise gently to

the north and sharply to the south. There is thus formed a true synclinal depression striking westwards, with a low pitch, into the English Channel. The complete disappearance of the fold on crossing the Cuckmere cannot be satisfactorily explained by the normal process of dying out, the distance being too short for so rapid a recovery. It is suggested, therefore, that a transverse fault may exist beneath the alluvium of that river, thus, perhaps, accounting for the narrow gorge at Cuckmere Haven. The top of the zone of *Marsupites testudinarius*, which lies in an approximately horizontal position at about the level of the 300 foot contour on one side of the river, sinks below sea-level in the trough of the fold on the other side. The fault, if it exists, seems to die away rapidly northwards, since no trace of it has been detected higher up the valley towards Alfriston. This feature would be expected from the nature of the movement. The relation of the Seaford fold to the main flexures of the South Coast is considered, and it is suggested that this fold represents the eastern termination of the structural area known as the Hampshire Basin, being, in fact, a continuation, *en échelon*, of the Purbeck–Isle of Wight system.

Certain existing physiographical features are ascribed to the influence of this flexure, which facilitated the retention of the Eocene cover in the synclinal hollow thus formed. A result of mapping the outcrops, also, has been to prove that the numerous dry valleys in this area are not of the nature of 'sinks' or 'dolinas', but are true valleys of surface-erosion. Attention is drawn to certain features of these valleys.

A brief comparison is made between the fossils of the inland exposures and those of the cliff-section, the most notable difference being the evidence in the former of a *Conulus*-band at the top of the zone of *Micraster cor-anguinum*.

II.—*May* 26, 1909.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, in the Chair.

The following communications were read:—

1. "The Cauldron Subsidence of Glen Coe and the Associated Igneous Phenomena." By Charles Thomas Clough, M.A., F.G.S., Herbert Brantwood Muff, B.A., F.G.S., and Edward Battersby Bailey, B.A., F.G.S.[1]

The succession of volcanic rocks in Glen Coe is mainly a series of lava-flows, of which there are three types—augite-andesite, hornblende-andesite, and rhyolite. Agglomerates, tuffs, and sediments form but a small portion of the sequence. The Lower Old Red Sandstone age of the rocks is proved by the occurrence of plant-remains in shales at the base. The sequence is divisible into groups, which are not, however, persistent over the whole area. Each group may contain different types of lava, which interdigitate one with the other. It is probable that the district was supplied from more than one centre, the foci being independent as regards type of material erupted, although their periods of activity overlapped.

[1] Communicated by permission of the Director of H.M. Geological Survey.

The volcanic pile, with patches of conglomerate and breccia at the base, rests upon an uneven floor, evidently a land-surface, of the Highland Schists; and further, the eruptions appear to have been subaerial.

The cauldron subsidence, which let down the volcanic rocks and the underlying schists some thousands of feet, affected an area roughly oval in shape and measuring 8 miles by 5. It is delimited by a fault, the hade of which is sometimes normal, sometimes reversed. The lavas abut against the fault-plane, and are frequently tilted up into a vertical or even overturned position near it. Further evidence for the boundary fault is afforded by the displacement of the outcrops of several members of the Highland Schists.

A zone about a mile wide lying immediately outside the boundary fault has been invaded by a number of masses of granite and porphyrite, spoken of collectively as the 'fault-intrusion'. Where the fault-intrusion comes against the boundary fault it is chilled, and its margin is a smooth even plane, while its junction with the schists is highly irregular. The fault-intrusion causes contact-alteration in the schists outside the fault, but the volcanic rocks and schists inside the fault are scarcely affected by it.

The movement along the fault-plane has caused intense shearing and crushing, leading finally to the production of 'flinty crush-rock'. The latter owes its characters to extreme trituration, probably accompanied by incipient fusion due to frictionally generated heat.

In certain places flanking faults older than the main boundary fault, and accompanied in each case by a mass of igneous rock on their outer walls, are found near the main boundary fault and parallel to it. The subsidence therefore took place in at least two stages.

After subsidence in the cauldron had ceased, a multitude of dykes, mainly porphyrites, but including quartz-porphyries and lamprophyres also, were intruded along lines trending north-north-eastwards and south-south-westwards. It is shown that the dykes add their width to that of the country traversed, and that they have their focus within the Etive granite mass. They have a parallel, not a radial arrangement; and a vast majority are concentrated into two swarms, which extend north-north-eastwards and south-south-westwards from the granite.

The authors discuss several questions arising out of their conclusions. With reference to the relative age of the faulting and the fault-intrusion, it is concluded that they are contemporaneous, and that the uprise of the magma may be considered as complementary to the subsidence. The Glen Coe subsidence is compared with the subsidence which took place in the Askja caldera in Iceland in 1875.

It is considered probable that the lobe of the Cruachan granite, which invaded the sunken area of Glen Coe, was admitted by a further subsidence of part of the rock-mass within the cauldron, and that the granite occupied the cavity thus formed.

A theory is advanced that the Cruachan granite mass also originated in a subsidence of the schists in place of which the granite is now found, the magma welling up the sides of the sinking mass and filling in the subterranean cauldron. Evidence for this is adduced in the

form of the intrusion, in the presence of a curved, flanking fault, and in the shearing of early consolidated parts of the mass.

The dykes point to the operation of regional tensional stresses which, co-operating with the pressure of the magma, opened parallel north-north-east and south-south-west fissures. It is suggested that the concentration of the dykes was due to the pasty condition of the internal parts of the granite mass, which yielded to the stresses and caused a localization of fissures in the surrounding solid rocks.

After the intrusion of the majority of the dykes, a further subsidence within the Cruachan granite mass admitted the central core of the Starav granite.

The principle underlying the interpretation of the phenomena described is the upward movement of igneous magmas in correlation with complementary subsidence of portions of the earth's crust.

2. "The Pitting of Flint Surfaces." By Cecil Carus-Wilson, F.R.S.E., F.G.S.

Regular pittings of uniform size are occasionally seen on flints which have been exposed to the weather. They have been referred to by various authors, but no satisfactory explanation of their origin has been given. The author procured some interesting examples occurring in a recent deposit near Folkestone. This deposit is formed of materials which appear to have been washed down from the adjacent chalk hills. The flints appear to have been derived from the sandpipes in the Chalk: their surfaces are much decomposed. The removal of the colloid silica has rendered them very porous, and they absorb a good deal of water. It is believed that the pittings are due to mechanical action. Observations and experiments carried out by the author indicate that such markings cannot have been produced by blows, nor by any process of desiccation, and that the freezing of the absorbed water seems to be the only satisfactory explanation to account for the various details of the phenomenon.

CORRESPONDENCE.

THE GENOTYPE OF *LOXONEMA*, PHILL.

Sir,—About a week after the publication of the Quart. Journ. Geol. Soc., vol. lxv, pt. ii, May, containing in full my paper on the genus *Loxonema*, read on January 13, I received vol. viii of *Essais de Paléoconchologie Comparée*, by M. Cossmann, published in April, but apparently only distributed in June.

It is impossible to bestow adequate praise on this admirable and laborious work, and I feel sorry to be obliged to differ on any point from its learned author. Nevertheless, I have unwittingly taken a different view with regard to the genotype of *Loxonema*, and I consider it advisable to give my reasons for so doing in greater detail. More especially do I feel the need of this since I also at first was in accord with M. Cossmann in taking the Devonian form erroneously described by Phillips as *L. sinuosum* (Sow.) for genotype (Quart. Journ. Geol. Soc., 1905, vol. lxi, p. 564). Further investigation, however, has convinced me that the Silurian *L. sinuosum*, described by Sowerby as *Terebra*? *sinuosa* (Sil. Syst., p. 619, and

pl. viii, fig. 15), must be the genotype. Two considerations have led to this conclusion.

1. Phillips mentions *L. sinuosum* first when enumerating species which he associates with it in the genus, and before he describes his Devonian form which he considers conspecific. When an author does not fix on a genotype it is usual to take as such his first-named species if represented by a sufficiently well preserved specimen, which is the case with this. Phillips' Devonian shell, being quite distinct, has no right to the name *sinuosum*.

2. The first author who clearly declares one of these species to be the genotype should be considered to decide the matter. I have shown that S. P. Woodward and P. Fischer are ambiguous. Lindström by implication selects *L. sinuosum* (Sow.) as genotype, but Professor Koken is the first to do so unequivocally, for in 1889 (Neues Jahrb. f. Miner. B.B., vi, p. 441) he states, "Der Typus ist *L. sinuosum* Sow. aus dem Obersilur." Again, in 1896 (Jahrb. der k.k. geolog. Reichsanstalt, Bd. xlvi, Heft i, p. 117 [81]), after discussing the different forms included by Phillips in the genus, he writes, "*L. sinuosa* Phill. ist also der Typus im wörtlichen Sinne, aber nicht die ganz typische Form, denn Sowerby's *Terebra sinuosa* aus dem Aymestrykalk mit welcher Phillips sie identificirt und welche der ideale Typus der Gattung ist, weicht nicht unbeträchtlich von der *sinuosa* des Clymenienkalkes ab. Wenn man die *echte*, obersilurische *L. sinuosa* Sow. sp. neben eine *Zygopleura* hält sieht man am besten, *wie weit* sich die letztere schon vom Ausgangspunkte der Gruppe entfernt."

Dr. Perner (Syst. Sil. Centre Bohême, pt. i, vol. iv, Gastéropodes, tome ii, 1907, p. 324) writes after the description of the genus, "Type: *Loxonema sinuosum* Sow." On p. 325 he divides the *Loxonema* into two groups, and on p. 327 calls the first "Groupe de Loxonema sinuosum Sow."

M. Cossmann (p. 16) seems to think that Koken considered *Terebra sinuosa*, Sow., a *Zygopleura*, but a reference to the passage quoted above shows the contrary to have been the case. In the preceding paragraph Koken writes, "Die letztere [*L. rugifera*], Phill. ist eine carbonische *Zygopleura*, verwandt mit der devonischen *costata Sdb.*, aber sehr verschieden von den Loxonemen der *Sinuosa*-Gruppe, auf welche der Name zu beschränken ist."

Since M. Cossmann (p. 18) has substituted the name *L. Perneri* for *L. propinquum*, Perner, which was preoccupied, and his work is prior in publication to mine, the species called *L. Perneri* by me (p. 221, and pl. xi, figs. 1–3) must yield to his, and I would therefore suggest the name *L. Cossmanni* for my species.

J. Longstaff.

Highlands, Putney Heath.
June 12, 1909.

ARCHÆAN OR LOWER PALÆOZOIC ROCKS IN THE MALAY PENINSULA.

Sir,—Dr. R. D. M. Verbeek, at the end of his "Rapport sur les Moluques" (edition Française du *Jaarboek van het Mijnwezen in*

Nederlandsch Oost-Indië, xxxvii, 1908, partie scientifique), gives a summary of the geology of the Moluccas and of the whole of the Netherlands Indies. Under the heading "Schistes Anciens" certain passages occur which may be translated as follows (p. 754): "Ancient schists without fossils, of which the age is unknown. Among these there are probably Archæan as well as old Palæozoic rocks. From a petrographic point of view we can distinguish gneiss, mica-schist, amphibole-schist, grauwacke, phyllite, argillaceous schist, etc. The amphibolites, whose silica percentage is generally low, but which contain much plagioclase, may by that be recognized as basic eruptive rocks, most often gabbros, metamorphosed and become schistose owing to orogenic movements. The other rocks are sediments more or less modified . . . (p. 755). The ancient schists are also widespread in the islands of the Celebes, Borneo, Karimown Djawa (Djapara Residency, Java), Billiton, Banka, Sumatra, and in the Peninsula of Malacca (i.e. the Malay Peninsula, I.B.S.). Although a part of these rocks may probably be azoic, among them are certainly others that are younger."

Seeing the recent date of Dr. Verbeek's Report, I think that his remark about ancient schists in the Peninsula calls for some notice.

I well remember, when I first came to the Federated Malay States, a conversation with an official of the Public Works Department, who assured me that a certain limestone in the north of Perak was Laurentian. On gently pressing for evidence, it appeared that the sole reason for this statement was that the Perak Limestone looked like Laurentian Limestone that my informant had seen in Canada some years before.

Had Dr. Verbeek but known that the evidence of the existence of Archæan or Lower Palæozoic rocks outcropping in the Malay Peninsula rested on such slender foundations as are exemplified above, I do not think he would have said that the ancient schists are widespread in this part of the East Indies; and, moreover, had the value of the evidence been better known, statements of a similar nature would not have crept into Professor Suess' *Der Antlitz der Erde* (Miss Sollas' translation, vol. i, pp. 456, 457. Here the term 'Archæan schist' occurs, vol. iii, p. 233. Here the Myophoria beds in Pahang are apparently included in the 'ancient sediments').

But for a small portion of Borneo, the geology of the Malay Archipelago is only known to me by the literature, and the question of the ancient schists in that region is therefore one on which I am not entitled to speak. But after a perusal of the scanty literature concerning the Peninsula, and five years' work in the country, I think I may say that as yet no evidence has come to light of rocks older than the Carboniferous, with the possible exception of inclusions of granite in tuffs and of a quartz-tourmaline rock in conglomerate, both being facts which are now published for the first time.

I trust I may be pardoned if I further trespass on your valuable space by mentioning another point in Dr. Verbeek's Report. On p. 756 Dr. Verbeek goes into some detail concerning the dip of the rocks at Mount Guthrie, Singapore, where I found certain fossils described in the 1906 volume of this Magazine by Mr. R. B. Newton. The dip observed by Dr. Verbeek and Dr. Molengraaf was opposite to that

observed by myself, and such is the stress laid on this that, although Dr. Verbeek kindly suggests a sharp anticline as an explanation, I felt, on reading the passage, misgivings as to the accuracy of my own statement. I have to-day re-examined the hill, and find that the section is more luminous than in 1906. Not only has much of the base been removed, exposing fresh rock, but a deep cutting has been made through the hill, cutting about N.N.W.–S.S.E., that is, parallel to the strike of the beds. The place where I observed the dip in 1906 was recognizable, and my observation was correct. The general dip is to the W.S.W., and this obtains at both ends of the cutting. There is, however, some evidence in the section (about 150 feet long) of apparently local but sharp folding and of faulting, such as is frequently seen in a disturbed area, but not of a distinct anticline affecting any considerable portion of the section. As a result of these folds and faults there are local dips to the E.N.E. in four places, while in four places the beds are vertical. The small quarry mentioned by Dr. Verbeek on the south side of the hill, which, but for the cutting, is now covered with grass, doubtless showed a local variation of dip. The matter seems to me to be of no great importance and not worth a figure of the section, but this explanation is due as much to Dr. Verbeek as to myself.

J. B. Scrivenor.

Singapore.
May 8, 1909.

CULM INCLUSION IN COARSE GRANITE.

Sir,—Although sedimentary inclusions in the granites of the Western Counties have often been described, the following occurrence may be worth a note. In the course of a walk from Lustleigh station to Foxworthy Mrs. Hunt called my attention to a fragment of rock protruding from a mass of granite lying by the roadside for road-metal. The roadmen then were clearing rocks in a neighbouring field, distant about two-thirds of a mile from the nearest granite boundary. The enclosing granite was of very coarse matrix with large orthoclases. The inclusion was a rhomboidal fragment of what seemed to have been a culm grit with planes of sedimentation, and with ordinary surfaces of fracture in the usual joint planes; weight about 1½ lb. The points of interest are that, though the fragment is completely crystallized, the boundaries are not dissolved or distorted. Before this very coarse enclosing granite was consolidated the fracture of the culm rocks was much as it is at present. Dr. Flett kindly confirmed my recognition of the fragment as sedimentary. Having seen much granite broken in the neighbourhood during the past twenty-five years for building and road-making, this particular specimen is unique of its kind in my experience. I have since noticed a triangular fragment in the same heap of stones, which I may possibly succeed in getting hold of.

A. R. Hunt.

May 6, 1909.

OBITUARY.

THOMAS MELLARD READE, F.G.S.,
Assoc. M. Inst. C. E., F.R.I.B.A.

Born May 27, 1832. Died May 26, 1909.

Mr. Mellard Reade was the younger son of William James Reade and Mary Mellard (of Newcastle-under-Lyme). His father, who was a man of high character and studious habits, but not successful from a worldly point of view, had in 1830 opened a school in Mill Street, Liverpool, and there Thomas Mellard Reade was born in 1832. Descended on the father's side from a family of Staffordshire yeomen, of whom the head member settled in Cheshire in 1730, there were among his kinsmen Sir Thomas Reade, Deputy Adjutant-General at St. Helena during Napoleon's captivity, and the Rev. Joseph Bancroft Reade, a pioneer in photography who was elected a Fellow of the Royal Society in 1838. On his mother's side he was a cousin of Mrs. Craik, authoress of *John Halifax, Gentleman*.

After receiving his elementary education in private schools at Liverpool and at Seacombe in Cheshire, Mellard Reade about the end of 1844, before he was 13 years of age, became a pupil in the office of Messrs. Eyes and Son, architects and surveyors, at Liverpool. In their office, and subsequently as a draughtsman in that of another local architect, Mr. H. Horner, he laboured diligently for a period of eight years. Early in 1853 he entered the service of the London and North-Western Railway at Warrington, becoming in due course principal draughtsman in the northern division of the Company's civil engineering department.

The knowledge and experience he had thus acquired during fifteen years enabled him in 1860 to commence private practice in Liverpool as an architect and civil engineer, and in this he was eminently successful. Among many works he laid out the residential estate of Blundellsands in 1865, fixing his own home there in 1868, after having married in 1866 the widow of Mr. Alfred Taylor, C.E. Appointed architect to the Liverpool School Board in 1870, he retained the office until 1902, having designed and superintended the erection and enlargement of many schools. He also carried out much other architectural and engineering work. In 1871 he was elected an Associate Member of the Institution of Civil Engineers and in 1878 a Fellow of the Royal Institute of British Architects.[1]

Although from boyhood he had been interested in science, and especially in geology, it was not until he was about 35 years of age that he began to give special attention to the subject. In 1870 he commenced the long series of geological articles which he communicated to scientific societies and journals, and in 1872 he was elected a Fellow of the Geological Society. His first important paper was on "The Geology and Physics of the Post-Glacial Period, as shown in the deposits and organic remains in Lancashire and Cheshire". This

[1] For most of the above particulars and for the supplementary list of his father's geological papers we are indebted to Mr. Aleyn Lyell Reade, author of *The Reades of Blackwood Hill*.

article was brought before the Liverpool Geological Society in 1871 and published in 1872, while the main facts and conclusions were printed in advance in the Geological Magazine for March, 1872. The full memoir, illustrated by colour-printed maps and sections, was a model of carefully recorded observations; and the author was enabled to make out the succession of changes which affected the region subsequent to the formation of the Boulder-clay. In particular he called attention to the marine Formby and Leasowe Beds which occur between the Inferior and Superior Peat and Forest Beds.

In 1873 he gave an account of the Buried Valley of the Mersey, and predicted that the tunnel which it was proposed to make beneath the river would intersect a gully filled with Boulder-clay. This was verified on the completion of the tunnel in 1885.

The Drift beds of the North-West of England and North Wales formed the subject of two papers brought before the Geological Society in 1873 and 1882, in which he maintained the glacio-marine origin of the Boulder-clay of the lower-levels, regarding as true Till, formed under or in front of the local glaciers, the Boulder-clay of the mountain regions.

He was elected President of the Liverpool Geological Society during the Sessions 1875–7, and again on two subsequent occasions, 1884–6 and 1895–7. In the address published in 1877 he took as his subject "Geological Time", giving tabulated calculations of the total solids in solution removed annually from each rainfall area and group of strata in England and Wales. This essay with additional matter was reprinted in 1879, in a little volume entitled *Chemical Denudation in relation to Geological Time*. It included also a paper on "Limestone as an Index of Geological Time", read before the Royal Society in 1879. Calculating the amount of carbonate and sulphate of lime carried away annually from the igneous rocks on the earth's surface, and the thickness of deposit that would result therefrom, Mellard Reade compared this with the assumed thickness of limestone in the sedimentary crust of the earth, and estimated that a period of about six hundred million years would be necessary for the entire series of stratified formations. Although subsequent researches tend greatly to lessen the estimates of geological time, he may justly be said to have initiated this instructive line of inquiry.

While he continued his researches on local geology he brought his experience on the Drifts to bear on other regions in the north and east of England, in Ireland and Scotland; and he gave much attention to Tidal Action as a Geological Cause, to Pebble Ridges, the Circulation of Water in Sandstone, the Physiography of the Trias, and other subjects.

In 1886 he published his important and elaborately illustrated volume, *The Origin of Mountain Ranges considered experimentally, structurally, dynamically, and in relation to their Geological History*. In it he brought forward the results of much original study and experiment, dealing especially with the effects of underground temperature on the expansion of rocks beneath thick accumulations which prevented the escape of heat, and led to folding, buckling, and uplift of the formations. He also for the first time pointed out

that at a certain depth in a cooling solid globe there must be a 'level-of-no-strain', a conception which has been generally recognized as of great significance in indicating that the disturbances are likely to be confined to a comparatively thin crust.

In recognition of this work and of his other contributions to geological science the Murchison Medal was awarded to him by the Council of the Geological Society in 1896, when Dr. Henry Woodward was President.

In 1903 Mellard Reade published *The Evolution of Earth Structure, with a theory of geomorphic changes*. In this work he explained the geographic relief of the globe as due (1) to differential alterations of volume in large sections, which take place with extreme slowness and, being deep-seated, upheave or depress portions of the earth's crust without wrinkling it; and (2) to the tangential creep and ridging up arising from the heating of sediments and variations of temperature, and consequent expansion, within the earth's crust brought about by sedimentary deposition. He further illustrated the subject with the results of many experiments on the folding and fracture of materials, and reproduced the account of investigations made in conjunction with Mr. Philip Holland on slaty cleavage. He also republished some essays on denudation, the permanence of oceans and continents, and other subjects bearing on the question of the structure of the earth and the origin of its main features.

During the last ten years Mr. Reade worked a good deal with Mr. Philip Holland, F.I.C., and together they published papers dealing with mechanical and chemical analyses of Ludlow rocks and Old Red Sandstone and Marl, and also with the subject of sands and sediments, treating these latter materials stratigraphically, microscopically, and chemically. From their observations the authors were impressed with the great amount of micro-sediment met with, such as the very fine powder of quartz which they termed quartz-dust. They observed that clay and iron-oxides are present in the clearest sea-water, and particles of carbonate of lime likewise occur, held up by the clay and not in solution. Finally they pointed out that the sea would carry about and distribute these micro-sediments, and thus make important additions to oceanic deposits.

The final paper by Mr. Mellard Reade, a short article on "The Mechanics of Overthrusts", was printed in the Geological Magazine for February of the present year.

Thus to the last he remained an indefatigable worker on dynamic geology and on the architecture of the earth's crust, subjects to which his professional experience advantageously and perhaps naturally led him. The business of his life indeed afforded him many opportunities, which he fully utilized, of seeing fresh sections of the strata, and it inculcated those methods of precision which characterized his records and experiments.

A severe illness during infancy produced a certain amount of deafness from which Mellard Reade suffered until the end of his days, and it increased with advancing years. On this account he rarely attended scientific meetings other than those of the Liverpool Geological Society. He printed two lists of his geological papers—